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CYBERNETICS AND MILITARY APPLICATIONS
(SELECTED PORTIONS)

by

V. A. Bokarev

FOREIGN TECHNOLOGY DIVISION

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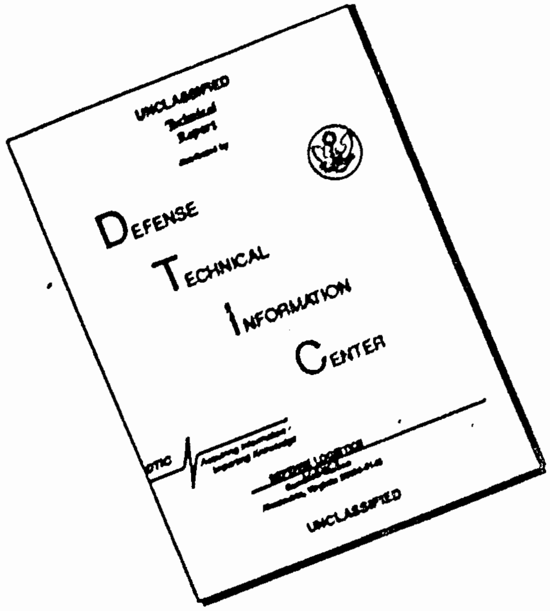

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13. ABSTRACT

In this work an attempt was undertaken from the positions of Marxist-Leninst philosopy and Soviet military science to discuss the philosophical bases of cybernetics and the methodology of its application in military affairs. The most important philosophical questions of cybernetics are the clarification of its object, method, volume and content of basic concepts, future of development, and its social (including military) value. The examination of methodological problems of the application of cybernetics in the military affairs proposes the discussion of questions of the specific nature of the sphere of control of a weapon and troops, of the paths for the perfection of systems and processes of control, of contradictions in this area, of automation as means of resolution of these contradictions, of the relationship of man and technology in the automated systems of control of troops, etc.

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U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

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Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
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Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
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К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

* ye initially, after vowels, and after ъ, ь; e elsewhere. When written as ё in Russian, transliterate as yё or ё. The use of diacritical marks is preferred, but such marks may be omitted when expediency dictates.

CHAPTER III

METHODOLOGICAL PROBLEMS OF CYBERNETIC MODELING AND LOGIC-MATHEMATICAL DESCRIPTION OF THE PROCESSES OF AN ARMED STRUGGLE

Electronic and mathematical modeling is the most important method of cybernetics. At the same time simulation is an important method in military-scientific investigation and the combat training of troops: maneuvers, command-staff studies, and field trials – models of combat actions, replacing them in peacetime. Radical conversions in military affairs made the simple transfer of past experience to present impossible, therefore frequently the means of checking military-scientific hypotheses can now be only a "quasi-practical" check on models, including electronic and mathematical models.

In this chapter consideration is given to the philosophical bases of simulation as a method of perception, the specific nature of cybernetic modeling, and its role in military affairs. Specific attention is given to the problem of the simulation of human psychology, inasmuch as successes in this area determine the boundarie of the possible and impossible in cybernetics and the future of development of "man – battle technology systems." A special section of the chapter is devoted to the problem of construction of logic-mathematical models of the processes of armed struggle. The future of automation of control of troops depends on the solution of this problem.

1. Methodological Problems of Cybernetic Modeling

The basic concept of cybernetics is the concept of the similarity of structure and functions of control systems of a various nature. Cybernetics as a science of the general laws of control exists because in systems of the most diverse nature the structure of cause-result bonds, algorithms of control, matrices of conversions, etc., are isomorphic. Therefore simultaneously with cybernetics the thought was born about the possibility of the modeling of systems and processes of control of the same nature with the help of analogous systems and processes of another nature. The method of modeling was so significant, that some even consider that the object of cybernetics is not control, but modeling, in particular the technical modeling of the functions of living organisms and human intellect.

However, modeling is not an object, but a method of cybernetics, which does not study the laws of simulation, but applies them for an analysis and synthesis of control systems. Moreover simulation is not a unique method of cybernetics. Methods of investigation and optimization of systems exist which are not connected with simulation. Let us take such an example. Now model investigations of the dermo-fatty layer of dolphins and the dynamics of their motion are being conducted with great success. The fact is that with relatively little power dolphins develop a paradoxically high speed. Apparently by this route it is possible to achieve a substantial improvement in the hydrodynamic qualities of submarines. There was also a report about the investigations of the design of the pterostigma on the wings of a dragonfly for the purpose of finding means for averting flutter on aircraft. In all their importance these investigations do not pertain to the competence of cybernetics, but to bionics, to aero- and hydrodynamics. Cybernetic and bionic simulation are merged only when they model the control systems of living organisms – their senses organs, nervous system, and the brain.

Modeling has very ancient sources and is connected genetically with entire object-instrument activity of man. But only in connection

with the development of cybernetics it turned from a semi-intuitive analogization into an original method of scientific perception. With the computer it became possible to create not only static, substrate-structural, but also dynamic functional models. As a result modeling became an effective, frequently unique method for the investigation of complex dynamic systems in biology, economics, and military affairs. It must be noted that the peculiarity of the present stage of development of science consists namely of the motion of matter - biological and social, the essence and the specific nature of which lie mainly in the complex system of organization of objects. It is not accidental therefore that a number of authors point out the process of "cybernetization" of contemporary science.

It must be noted that today the concept of "cybernetic modeling" is used in the literature in two meanings. First in the broad sense, when they want to distinguish the present stage of development of simulation from the previous "pre-cybernetic." Secondly in a narrow meaning when they want to distinguish the simulation of control systems from the simulation of any other systems. Unfortunately this terminology was already formed, and only the calculation of the context in which this expression is used is free from confusion.

Cybernetic simulation (in both meanings) did not become the object of philosophical-methodological investigation at once. For a long time instead of the detailed analysis of the ontological bases and gnoseological nature of the method of simulation on the whole, the interests of the majority of authors were concentrated on the unique problem of this circle - the question of the possibility of the simulation of human intellect. Although the question of how far the isomorphism of a machine and the brain extends is important and interesting, this problem, which became unique, turned into an unusual brake. Only in recent years did solid investigations appear which were devoted to simulation on the whole.[1]

[1]See V. A. Shtoff. The role of models in knowledge. LGU Publishing House, 1963; I. B. Novik. The simulation of complex systems (a philosophical outline). "Mysl'" Publishing House, 1965; B. A. Glinskiy et al. Simulation as a method of scientific investigation. MGU Publishing House, 1965.

Nevertheless philosophical-methodological elements have an important effect on the success of a model investigation. The construction of a model requires not only a formal-logical thought on a prepared algorithm, but also creative power, imagination, and intuition. Therefore here to the greatest measure is manifested the ideology of the scientist. When F. Hoyle in his cosmogonical model of the world includes such an initial condition as "the creation of matter from nothing," this is the result of his idealistic outlook. Conversely, the heliocentric model of the solar system of Copernicus, the Rutherford model of the atom, or the models of organic molecules created by Butterov are the consequence of the materialist ideology of these scientists.

In the simulation of mechanical, physical, and chemical phenomena the elementary materialism of the scientist proves to be a sufficiently reliable compass. However, cybernetic simulation stepped over the boundaries of these three forms of motion of matter. The models of complex biological and social systems do not possess an elementary clarity, and that is why only "common sense" becomes insufficient; indeed elementary materialism in most cases does not rise to the scientific explanation of life, psychology, and social-historic processes.

The model investigation of armed struggle requires the development of a number of methodological problems. For example, models of the type of command-staff studies will produce high-quality scientific information only in the case when the methods of determination of the degree of isomorphism of the object and model, the means of transfer of information from the model to the object, etc., are thoroughly investigated. In other words, it is impossible to say that in this model it is reliable and in that it is conjectural.

In recent years in connection with the development of simulation as a method of knowledge there has been much dispute over *what is such a model*. While simulation played the role of a secondary method, which was applied in a few branches of science, the models themselves

were elementary, this notion was of no interest to anyone. Interest in its investigation developed when it turned out that simulation is the most important general-scientific method.

The concept of a model is very varied. Artists name as a model the live model, from which a canvas is painted, and in science the model is frequently the simplified arrangement of any object, for example an atom. As we see, in some cases a model is that from which a copy is made, and in others – the copy itself. However, here there is no arbitrariness or confusion. It is simply necessary to distinguish the place of a model in the process of perception of an object and in the process of its reproduction.

In an investigation, in perception a model follows an object, it is a pattern of it, and in reproduction, in engineering, conversely, the object follows the model and is a pattern of it. For example, during the investigation of the dynamics of an engagement of a fighter airplane with a bomber an electronic model is the copy of the actual battle, and in the process of the creation of new form of armament a structural model comes forward as a sample for the creation of series objects.

The objective base and characteristic feature of any simulation is the presence of a similarity between the model and object being simulated. This generality expresses itself in the homomorphic or isomorphic correspondence of the object and model.

The questions of classification of models are completely complex and still weakly developed. Some authors propose to distinguish cognitive (gnosiological) and practical-technical models (model-substitutes, imitators, equivalents). In other works it is planned to divide models into informative and constructive-energetic (for example, the prostheses of the extremities). In all appearance, all gnosiological models are informative and among practical-technical both informative (for example, calculators and plotters in bombsights) and constructive-energetic (antenna equivalents).

In this work mainly informative models are considered, since namely they are applied during a theoretical investigation and in the practical work of systems for the control of troops and weapons.

Several points of view exist on the volume and content of the concept of an informative model. The first of them is reduced to the fact that a model is any object, process, or system, in any respect similar to another object, process or system. Schematically this looks as is shown in Fig. 3.1. Such a point of view is held by the compilers of the Philosophical Encyclopedia.[1] In accordance with this concept any isomorphic systems are models of each other. Note, not only *may*, but *are* models. Thus isomorphism is not only necessary, but also a sufficient condition that the objects be models. Moreover this ratio is symmetric, two isomorphic objects reciprocally model each other.

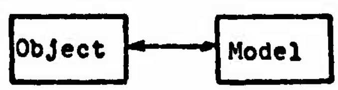

Fig. 3.1.

If we agree with this point of view, then one ought to recognize that the concept of model relation is altogether only a new name of a homomorphic or isomorphic relation. With such an approach this concept does not expose anything specifically inherent to the method of simulation and it does not carry any new information, which was not contained in the concepts of "object" and "isomorphism."

More fruitful is the concept of A. A. Zinov'yev, I. I. Revzin, I. B. Novik, and A. P. Dmitriyev.[2] They stem from the premise that simulation is a specific cognitive method, when the subject instead of the direct investigation of the object of knowledge selects or creates a similar auxiliary object-substitute, investigates it, and transfers the information obtained to the object-original. With such

[1] See Philosophical Encyclopedia, Vol. 3, page 481.

[2] See A. A. Zinov'yev, I. I. Revzin. The logical model as a means of scientific investigation. "Voprosy filosofii," 1960, No. 1; I. B. Novik. About the simulation of complex systems "Mysl'" Pub. House, 1965.

an approach the most active role belongs to a perceptive subject: a model situation appears according to its initiative, the cognitive assignment assigned to it determines the required measure and form of similarity of the model and object, moreover more frequently it does not simply select, but constructs the model. Let us say in creating an electronic model of the system of control of a pilotless airplane-interceptor, the investigator thinks over ahead of time the differential equations of which order should solve its arrangement. Otherwise it will not be a model. Without a perceptive subject any objects, no matter how similar to one another, remain "rank and file" physical bodies, and their isomorphic similarities - only a prerequisite, thanks to which one of them can in the process of knowledge become the model of the other.

Simulation proposes the presence not of two (an object and a model), but of three elements - a subject, an object, and a model. Schematically this situation is depicted as is shown in Fig. 3.2. Such a treatment of a simulation readily explains the finesse of the interdependence of subject, object, and model in the process of physical, mathematical, and electronic simulation.

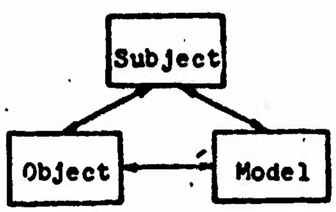

Fig. 3.2.

This diagram "operates" also in the case of mental simulation, to which commanders and engineers resort very frequently. Here, however, some explanations are necessary.

Mental simulation is a cognitive method when a man creates in his head the perfect model of an object, investigates it or conducts a mental experiment, and then transfers the results to the object. In this instance the model is found in the head of the subject and this situation apparently cannot be shown as a triangle, as in Fig. 3.2.

The majority of authors, who maintain the "three-element" concept, prove its generality in an example of *material* models, but then, when the turn reaches the analysis of mental models, then, without pointed attention to the specific nature of simulation, in the category of models they include all mental forms. This occurs because frequently authors consider mental simulation as a particular, not very important method and they do not strive for a high strictness of analysis. However, this is far from being so. Before building or selecting a material model, man constructs it mentally. Further the fate of the model depends on its complexity and elaboration of the methods of investigation. Those models, with which man freely operates in his head, also remain mental. The others are printed on paper in the form of sign models of various types (drafts, map, plans, charts, formulas, etc.). And only some of the mental and sign models are materialized in material systems, for example in a computer.[1] In this way, without investigating the nature of mental simulation, one cannot consider the problem of simulation solved in general.

The complexity of the question lies in the fact that it is difficult to distinguish mental models from a number of other types of a psychic representation. Frequently the notions of model and mental pattern are used as synonyms. "Knowledge is simulation, the brain is an enormous simulating device," writes professor N. M. Amosov. Actually any theory, inasmuch as it is isomorphic to the investigated object, can be used in the capacity of its mental model. However, recognizing the concepts of "an ideal pattern" and "a mental model" as synonyms, we are making a purely literary, but not scientific acquisition: any specific nature of mental simulation as a specific cognitive method is not revealed. Who will gain from consciousness

[1]The majority of attempts to give a logically orderly classification of models proved to be not completely successful, because the models are taken in statics, are outside the process of simulation. Genetically connected, turning from one into another in the process of knowledge, in schemes they appear disconnected and fixed. Only having presented them as the product of specific stages of the process of knowledge is it possible to understand what is the real connection between the various forms of models.

of that fact that each application of a mathematical formula is mental simulation?[1]

The process of mental simulation flows thusly. The pattern being created in the head of man (whether it be concrete-sensual or abstract-logical) to a certain degree is isomorphic to the object depicted in it. At the same time a mental pattern is not identical to the object: as a result of abstraction from secondary the substantial features of an object in a representation can come forward more brightly than in the original. However, a pattern becomes a model only when the perceptive subject (perceptively or intuitively) resorts to the operation of averaging and, instead of directly investigating the known object, directs its forces to the study on the structure and features of its mental representation in order that the information obtained in this case be transferred subsequently to the known object itself. Otherwise the pattern will not become a model.

Let us examine an example, when in the capacity of the model a sufficiently developed theory is used, for example, the theory of automatic regulation. Its logical structure and mathematical apparatus reflect the practical physical structure and the laws of functioning of objects. Therefore the features, connections, and the relationship of the theory itself, having become the object of independent investigation, can serve as the source of information about features, connections, and the relationships of objects. For this first of all the degree of similarity of the theory and the object is determined.

In investigating the axiomatics, a conceptual fund, the structure of the logical apparatus, and the connection of the situations included in the theory, and in analyzing mathematical apparatus and even the features of symbolism, new, previously unknown information is obtained. However, at this stage of investigation the information obtained refers only to the model itself and it does not have a relationship to the object. Therefore the final stage of mental

[1]V. A. Shtoff writes the any perfect pattern can be considered as a mental model of the phenomenon being reflected (see the "Role of Models and Knowledge," page 21).

simulation is the operation of transfer of information obtained from the model to the object. Most frequently this transfer acquires the nature of a concise interpretation of a formal-logical or mathematical result. In this way in physics several features of elementary particles were discovered - strangeness, a barion number, isotopic spin, and hypercharge. In investigating the logic-mathematical structure of a theory, physicists at first introduced these notions formally, and only then they approached the search for their physical interpretation. Likewise is the matter when, having examined an abstract model of battle actions, a commander passes over to the concise tactical interpretation of the result.

One can assume, that man resorts to mental *simulation much more frequently than this is recorded* consciously. The utilization of concrete-sensual patterns in the capacity of models, as a rule, proceeds intuitively. For example, fliers relate that sometimes they seemingly see their aircraft and its trajectory from the side. Abstract-logical models require one or another degree of realization of the actions of the subject.

Inasmuch as in the capacity of an abstract model most frequently a formal logic-mathematical apparatus is used, and not the concise components of a theory (initial premises, principles, conclusions, interpretation), then the investigation and realized application of a mental simulation was begun namely in those sciences, in which this apparatus has a great specific importance. Therefore also in military-scientific investigations simulation penetrates sufficiently the mathematization of military science. However, also in the abstract-logical area sometimes it is possible to observe how an investigator spontaneously, unconsciously passes over from the examination of the object itself to the analysis of the structure of the theory describing this object. Some authors, for example, from an analysis of the very systems and processes for the control of troops accomplish an "imperceptible" passage to the examination of the description of control given in this or that work. Inasmuch as neither the isomorphism of the object and the model, nor the rules of an interpretation in this instance are investigated specially, then in this case not only errors, but also crude gross errors are possible.

While the model is rather simple, it can be operated in the head and it remains mental at all stages of the investigation. However, a model, let us say of such a system as an automatic pilot, is difficult to retain in memory and man is forced to resort to recording. So *sign models* appear, the cognitive role of which recently has increased sharply.

Methodological difficulties during the investigation of such models are begun from doubt, sign models are considered mental or material. The problem was especially complicated with the advent of the computer: on the one hand the models in a computer are doubtlessly material, on the other hand, they are found in just as much an obvious relationship with sign models, and through them — with mental models.

In order to analyze the nature of sign models, let us turn first of all to the data of semiotics — a science dealing with the investigation of the general features and characteristics of signs and of sign systems.[1] A sign, write the specialists in semiotics, is that stimulus which plays the part of a signal of another stimulus. If the stimulus causes an effect only on itself and does not signal anything outside, then it is not a sign.

At first glance it follows hence, as if any sign can play the part of the model of an object: a sign — this is a signal, and a signal, as is known, is isomorphic to the described object. However, signs differ. There are sign-copies and lingual signs. A sign-copy is a reproduction of the object being designated. Such, for example are photographs, topographic maps, drafts and fingerprints. Such signs are isomorphic to objects and they can play the part of their models, moreover material models.

An entirely different role in simulation is played by lingual signs, which enter into the composition of natural or artificial

[1]See L. O. Reznikov. Gnosiclogical questions of semiotics. LGU Publishing House, 1964; A. A. Vetrov. Semiotics and its basic problems. Politizdat, 1968.

languages. (Artificial languages include formal-logical and mathematical calculations, code systems, information-logic languages for the composition of computer programs, etc.) Lingual signs in contrast to sign-copies are not able to replace the designated object. These signs do not resemble the designated object at all. Actually, neither the configuration nor the mutual disposition of symbols

$$U_c = \frac{1}{c}\int_0^t i(t)\,dt$$

in no way resemble the process of change in voltage in armatures. With the porcess that is similar which stands after these signs in our memory — patterns, representations, concepts. A model is not the sign itself as such, but its value.[1]

The latter leads to the fact that sign models have a dual nature. Actually, inasmuch as the model itself is not transferred to the paper, but its arbitrary designation (its own kind of "small bundle for storage"), then simulation in essence remains mental. On the other hand, for man, who knows the alphabet, the signs on paper actually come forward in the capacity of a material model of a practical process.

The key to the understanding of this duality is the active role of the cognizant subject: he places the signs in correspondence to the object, and these signs are isomorphic to the object only for him. Perhaps the "behavior" of a sign model can be compared with the behavior of a virus. As is known, a virus lives only when it is found in a living cell. Outside a cell it is an inanimate structure, able to activate again only when it enters a cell. A mental model "lives" inasmuch as the subject operates with it as a means of knowledge. A sign system turns into its own kind of "spore," it

[1]Lingual signs are genetically connected with sign-copies and other nonlingual signs. They resulted from figures, following the visual patterns of practical objects. The graphic similarity disappears gradually, in proportion to the increase in the ability of people for abstracting. But still even now in some lingual signs the traces of a figure have been preserved. For example, roman numerals I, II, III are evidently copied from the human fingers, V — with five fingers, and X apparently represents two groups of five fingers put together.

temporarily dies when it remains on paper, but it is ready to be turned into a model in the head of the man who knows its alphabet. Thus an experienced commander in a fixed, it would seem, tactical arrangement sees the dynamics of battle.

Both mental and sign simulation along with advantages possess shortcomings. Mental models are dynamic, are able to reproduce not only the separate states of an object, but also the processes of its functioning. However, they are not sufficiently "spacious": man cannot operate in his head with very large models, "beating" him with their complexity, let us say with such as a model of the air defense system of a country. Sign models, conversely, in principle can be as large as desired, but they are static even in the case when in their recordings they reflect the dynamics of processes. Therefore the further development of mental and sign simulation is connected with the utilization of *electronic computers*. In a computer the synthesis of advantages and mutual compensation of shortcomings of this and that types of models is attained: here models are created which can be called dynamic signs of "quasi-mental" models. In essence the computer models not only the investigated phenomenon, but partly also the modeling subject. More exactly it models its ability to operate with sign models.

The utilization of digital and analog computers for simulation led, in the essence of the matter, to the second generation of simulation as a method of scientific knowledge. The distinctions of cybernetic simulation (in the broad sense of this notion) from pre-cybernetic are so substantial that one ought to dwell on them separately.

Cybernetic simulation — this is *simulation of complex systems*, which are complex not only in a substrate and structural, but also in a functional respect.[1] Pre-cybernetic simulation was applied there

[1]It must be noted that the concept of complexity has still not been developed sufficiently. Thus, according to Ashby a system is complex if in something "it beats" the investigator. With such an approach only the characteristic of the subjective perception of

where systems either were simple or could be separated into simple components. Biological and social systems, as a rule, are distinguished by the fact that an attempt to decompose them in the process of investigation into simple elements leads to the obliteration of the very object of investigation, i.e., those specific regularities which are manifested only in an integral system. For example, having decomposed the brain into separate neurons, it is possible to investigate chemical and, at the best, biological regularities of the work of a brain, but by no means psychic: the latter are the function of the integral brain. Having divided the military association into separate, nonconnected people, nothing can be learned about the regularities of formation of the sense of military duty, of army comradeship, and so forth.

Up to the appearance of cybernetics and the computer attempts to take into account the true complexity of phenomena often led only to the exposure of general tendencies: "with an increase of this or that it increases (it diminishes)." The absence of calculation of the complexity of the investigated systems, as a rule, led to mechanization or to trivial results: "if we do not consider the moral factor and the ability of command personnel, then two battalions are stronger than one."

Digital and analog machines, and in particular analog-digital complexes which have been developed in recent years made it possible

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[FOOTNOTE CONTINUED FROM PRECEDING PAGE]: complexity is exposed by an investigator. The objective basis remains in a shadow. There is interest in the attempt of I. B. Novik to introduce the quantitative criterion of complexity of systems. This criterion is defined as "the relationship of the number of classes of external pressures, which a system is able to balance, to the number of already known classes of pressures, with which a system is not in a state to be balanced. (For the simulation of complex systems, see page 104).* It is possible to argue about how far such a criterion is correct, however, it possesses two advantages: in the first place it is more objective than the criterion of Ashby, in the second place it determines complexity not through static substrate or structural indices, but through indices of dynamic functioning.

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to construct models of complex phenomena with completely permissible simplifications. In these models processes which are described by a complex system of differential equations are examined thoroughly, numerical integration is carried out freely, and there is the possibility to simulate the processes, described not by a formula, but by an algorithm. It is important to note that during simulation on a computer it is possible to carry out a sufficient quantity of realizations of the investigated process in an abbreviated scale of time. This produces rich statistical material, the obtaining of which, let us say in the course of army maneuvers, would require years and expenditures of millions, furthermore, the possibility is opened to compare the hundreds of the variants of a process and to select the optimum one. For example, it is possible to investigate, which battle formations are the best under conditions of utilization of weapons of mass destruction, and to find the optimum, which ensures the least losses with the best interaction and coordination of fire of the subunits.

In the scientific research establishments of the US Army such models are constructed to investigate the dynamics of combined-arms combat. Each element of the memory device of the machine contains data about one of the active objects (a platoon of infantry, a tank, an artillery battery) or about one of the passive objects (forest, mountain, local objects, minefield). Into the memory device the coordinates of objects on the battlefield and some of their characteristics are fed. For passive objects characteristics are the degree of their limitation of visibility, difficulties of movement and so forth. For active - the firing range, the rate of movement and so forth. The behavior of each active object is decomposed into three stages: the selection of target for firing, firing, and movement to the new position. The selection of a target depends on the tactical-technical characteristics of the object and the target, on the assigned mission, and the situation. After each "shot" the arithmetical device of the computer conducts for each target an appraisal of the hit probability and then it assigns to some of them damages, and if they should be completely knocked out excludes them

from the memory device. Then the active objects are moved to new positions in accordance with the tactical assignment, situation and the conditions of the terrain.[1]

Having developed the methods for investigation of complex systems, cybernetics, according to Ashby, became "the first strict science of complexity."

The second important feature of cybernetic simulation lies in the fact that this is simulation of dynamic systems, mainly systems of complex dynamism. The term "dynamic system" is not single-valued. In an encyclopedia, for example, it is defined thusly: "a dynamic system is the totality of physical objects, the state of which changes with time".[2] Strictly speaking, this definition will cover any objects, since in the world there are no nondynamic systems in this meaning. However specialists in automation and cybernetics have introduced a specific meaning in this concept. They have in mind not physical objects as such, but only that aspect of them which is described by equations of a given type and is considered in a given relationship. Let us say that only mechanical movements of elements of a system have been taken for examination. In this case any fixed design in a mechanical respect is not considered dynamic, although it is known, that in its elements continuous physical and chemical changes are taking place. In another case and in another respect this system itself can be recognized as dynamic.

However, the meaning of the concept "dynamic system" is not ex exhausted by this. During a prolonged period of time science had a rule in effect: "change faktors one at a time." This was an effective and reasonable method of investigation, inasmuch as the investigated objects themselves allowed such an approach to their study. In

[1]See V. S. Sinyak. Military utilization of electronic computers. Voyenizdat, 1963, page 123-127.

[2]Encyclopedia "The Automation of Production and Industrial Electronic Engineering," Vol. I, page 329.

investigating, for example, the dependence of the state of a gas on temperature, pressure, and volume, it followed initially to observe the dependence of pressure on volume at room temperature, then the dependence of pressure on temperature at a constant volume, and so forth. In this way the equations of Gay-Lussac, Boyle-Mariotte, and Clapeyron were obtained. However, biological and social system do not allow this approach: having changed one of the parameters, we inevitably change all or the majority of the remaining ones, moreover there is no possibility to compensate or even to follow all the changes. So it proceeds during the investigation of the dynamics of price formation: the prices of all industrial goods and foodstuffs are interconnected so tightly, that the change in a price of one of the types of goods causes an avalanche-type chain reaction. For the analysis of such systems a method developed by cybernetics is applied in which the parameters of the system change not "by one" but in a complex: the entire totality of output parameters is placed in correspondence to the entire totality of the states of the input parameters of the system. The effectiveness of this method is multiplied, when the matrices of the states of the system are analyzed not "manually" but with the help of a computer.[1]

An important feature of dynamism is noted by N. Wiener. He indicates that one ought to distinguish reversible and irreversible processes. In the first a cyclic recurrence is observed, a repetition, a "reversal" of the process is admissible. For example, if we take a motion picture about the motion of planets and then start this film in the opposite direction, then we will not see any disturbance of Newtonian mechanics. In irreversible processes repetition either is not observed at all, or it is eroded. If in the equations of the turbulent motion of clouds in the area of a thunderstorm front we replace the variable t by $-t$, then completely improbable, contradictory the laws of a nature, picture is obtained. The changes in the systems, being invest_gated and created by cybernetics, bear a complex, irreversible nature and are connected with development.

[1]See W. Ross Ashby. Introduction to cybernetics, Chapter I.

The processes of armed struggle also bear an irreversible nature, the development of combat actions, as a rule, does not lead to word-for-word repetition of past situations. Therefore it is necessary to become closely acquainted with the problem of simulation of development.

In recent years the problem of simulation of developing systems has been attracting ever greater attention. In a number of works this problem was discussed in passing,[1] and works have already appeared which are specially dedicated to this question, for example the article by L. V. Smirnov, "Mathematical simulation of development."[2] In spite of some inaccuracies, in this article a number of remarks are made which deserve attention. In the first place, author correctly indicates that any model, depicting the essence of development, should be probabilistic: during the transition of a system from one state into another only some possibilities will be realized. This explains the irreversibility of a process, since the system cannot describe accurately the same trajectory in the opposite direction. In the second place, the author correctly notes that the most suitable mathematical apparatus for the description of a development are "Markov chains" — a specific type of random processes investigated by the prominent Russian mathematician A. A. Markov. The Markov chain is that sequence of random process, in which the outcome of the given experiment depends on the outcome of a preceding experiment, but does not depend on the outcome of earlier experiments.[3] Such a sequence recreates substantial aspects of a development because "heredity" and "changeability" of a developing system are combined, its simultaneous dependence and independence on preceding states.

[1]See M. S. Bartlett. Introduction to the theory of random processes. Publ. House for foreign literature, 1958; V. S. Nemchinov. Economic-mathematical methods and models. Sotsekgiz, 1962; N. M. Amosov. The simulation of thought and psychics. Kiyev. Publ. House "Naukava dumka," 1965.

[2]See "Problemy filosofic," 1965, No. 1, page 67.

[3]For a more exact definition of the Markov process see J. Kemeni, J. Snell and J. Thompson. The introduction to finite mathematics, page 212.

It is difficult without a thorough investigation to say how substantial are those aspects of the process of development which are reflected by a Markov chain. All the more so it is difficult to judge if this apparatus is suitable for all processes of development. However, it is possible to express hope that a rather broad class of processes of armed struggle can be modeled with the help of this apparatus.

A substantial feature of the process of development is also the fact that its source is included in the developing phenomenon itself. In speaking about development, they usually have in mind namely *self-development*. The simulation of this feature of development is still the most complex problem. However, the development of self-organizing, and in the future self-reproducing devices, will apparently allow the overcoming of this difficulty also.

Cybernetic simulation is still functional simulation, i.e., such in which external similarities are not attained, no similarities in the nature of elements, and even no structural similarity of systems, but mainly the similarities of behavior of the model and the object. For pre-cybernetic simulation a characteristic is the substrate-attributive approach, in which it is considered that to investigate an object means to learn of what elements it consists and what properties these elements possess. Only after this the interaction of elements and the structure of the system are investigated and finally conclusions are made about the possible types of functioning of an object. On the whole this is an effective and fruitful method. For example, the investigation of the combat qualities of a soldier allows the making of important conclusions relative to the structure and combat capabilities of an army on the whole. However, along with advantages this method also possesses shortcomings, which led to the appearance of the functional method of investigation.

The rudiments of the functional method are already contained in the approach of Newton to the investigation of the problems of gravity. It is known that many physicists, including Hooke and

Huygens, attempted to investigate the nature of gravity by the substrate-attributive method, i.e. to find the "matter" of gravity and to determine its properties. Newton did not start to conduct a "frontal attack" on gravitation quantum, but circumvented this difficulty by the fact that he gave a formal-mathematical, in essence functional, expression of the law of universal gravity. This approach is characteristic for Pavlov investigations of the reflexes of the brain, where main attention was turned not to the structural-attributive investigation of the internal mechanism of the brain, but to the behavior of animals and the interaction of organisms with the environment.

Functional simulation appeared later than the substrate-attributive because it was rather complex in a theoretical-cognitive respect and it proposes a double abstraction - from the substrate of the object and from its structure. Inasmuch as in the development of one form of models in an abbreviated form the genesis of the entire method of simulation on the whole is reflected, then this can be observed in such an example. In the clinic of Academician B. V. Petrovskiy operations are conducted on the transplant of an artificial mitral valve of a heart in the case of hopeless defect of the natural valve. In comparing the models created in chronological order, it is possible to note, that in the beginning they copied in detail even the consistency of the tissue of the living valve, then the similarity of material is lost, but the structural similarities are retained, and finally the latest models are similar to the original only in functions.[1]

In the course of functional simulation the similarity of phenomena is replaced by the similarity of substances. A model of combat in a computer is outwardly less similar to the original than

[1]Nothing more similar can be observed in the development of a weapon: a club with a thickening at the end directly copies a hand with a closed fist. Later such an external similarity reverts to secondary significance. The main place is occupied by the reproduction of repeatedly amplified functions of the hand as a means of struggle.

a model of it in a sandbox, however, the first makes it possible to reveal the dynamic functional characteristics, and the second not.

The functional approach is connected with using the concept "black box." The concept "black box" was suggested by W. Ross Ashby. This is the name given to an investigated object, the interior equipment of which in this stage of investigation for some reasons (complexity, danger, remoteness, inaccessibility, absence of methods and means) is not considered, it is as if covered by an opaque lid and only the channels of communication of the object with the environment are found in view – its entrances and exits.

Two trends are distinguished in the utilization of the concept "black box." The first consists of the fact that a set of "black boxes" with an assigned behavior is used in the capacity of prepared blocks, from which the system is synthesized. For example, it is necessary to design a system of automatic control. To begin with transistor components, capacitors, and resistances cannot be done: the trifles will suffocate the main concept. Therefore for a period one must "forget" about the content of the assemblies of the system and operate with them as "black boxes," the interior equipment of which can be any, only that with assigned signals at their inputs there were assigned signals at outputs. Such "black boxes" in the theory of automatic regulation are called the standard links, from which, as from cubes, automatic machines for any purpose are made.

Approximately likewise this method is applied by electricians and radio operators. In electrical engineering it is known as the method of a two-terminal pair network (and multiterminal networks). Radio operators also initially make up a block diagram of devices from "small squares": "oscillator," "amplifier," "detector," etc., join them with arrows, characterizing the functional connections of the scheme, and after that they begin to think about their contents. Under various names and at a different level of theoretical-methodological strictness this method is applied in many areas, let us say when developing the organizational-staff structures for headquarters, but cybernetics for the first time approached its fundamental substantiation.

The described means of utilisation of the concept "a black box" is used in the synthesis of systems. However, this concept can also be useful in the course of their investigation. The essence of the method is that, having met an unknown object and being convinced that it is rather complex, we do not rush to take up a screw-driver in order to dismantle it into separate little wheels and screws, but initially we study its behavior on the whole. Such a study gives the investigator a set of official recordings: "when the inputs of the system are found in states $x_1, x_2, \ldots, x_n$, the outputs of the system are found in states $y_1, y_2, \ldots, y_m$." If there is already experience in the investigation of such systems, then in the capacity of input signals specially selected standard combinations are used. Such is the approach in the experimental taking of frequency, phase and other characteristics of elements of systems of automatic regulation. However, in general on the input the practical pressures of the environment can be conveyed. This happens frequently during sociological and economic investigations. The further course of investigation depends on how strict the official recording is. If the states of the inputs and outputs were evaluated subjectively, then results will bear a purely appraisable nature. Unfortunately, many investigations in the area of humanitarian sciences still accomplish just that. If states x_i and y_j were evaluated by an objective measure (note, not compulsory quantitative, the main thing is objective), then it is possible to obtain a strict logic-mathematical description of the behavior of the system. Depending on the nature of the interdependence between the inputs and outputs the description acquires the form of a formula (for example, a differential equation), an algorithm, or it bears a statistical nature. To describe a system by differential equations is possible rather rarely. More frequently it proves to be possible to establish an algorithm for the answer of the "black box" to the input signal. In a general case a statistical description of it is obtained, i.e., the distribution of the probabilities of possible states of outputs of the system for each combination of signals at the inputs. In this way functional simulation makes it possible to solve many particular assignments in the absence of a general theory.

In connection with what was said above it is necessary to make two remarks which are important in a methodological meaning. The first is that the functional method has nothing in common with pragmatism. Pragmatism, as is known, is a subjective-idealistic flow, the main principle of which is that knowledge is recognized as true, which in this case "works" better on the subject. For example, the dogmas of religion, if they in this case are useful to a subject, they are considered as its personal subjective truths. A functional method is called on to force the investigated system "to operate," i.e., to indicate a means to control it until its interior mechanism will be completely investigated. Let us say it would be very useful if until psychologists investigate "to the end" the interior mechanisms of the shaping of combat spirit, they learn to completely reliably and effectively control this process. For a counterbalance to pragmatism the functional method stems from the acknowledgement of the objectivity of truth and it strives toward its expansion, and does not construct arbitrarily subjective substitutes of truth. The fact that this method under specific conditions gives practically useful knowledge earlier and with less investments than any other scientific method testifies to its scientific effectiveness.

The second observation is that the concept of "black box" has nothing in common with behaviorism. Behaviorism (from the English behavior) is one of the trends of foreign psychology, the representatives of which consider that the interior mechanism of psychics is not subject to investigation and the assignment of a psychological investigation is the establishment of correlative bonds between stimuli and the reactions of an organism to them. In other words, the behaviorists consider that one should not open "black boxes."

A functional approach is contrary to behaviorism: a logic-mathematical description of a "black box," in the essence of the matter, is one of the possible models of its interior mechanism. A "box," the mathematical description of which has already been received, ceases to be "black," and turns, according to the accurate expression of M. G. Haase-Rapoport, into a "gray box." The described method is means of expansion, of X-raying "black boxes."

Speaking about the effectiveness of functional simulation, it is important, however, to note that structure and function of a system in general do not have a rigid, mutually single-valued connection. This connection bears a statistical nature. The functional model reproduces only one of the structures, in which such a functioning is possible. Having established the identity of the functions of two systems, the identity of their structure still cannot be concluded. Only an *absolute* identity of functions could testify to the identity of structures, however, practice as a rule does not give proofs of absoluteness.

Therefore functional simulation cannot and should not be the final point of an investigation. Having revealed with its help the regularities of functioning of an object and of its connection with the environment, an investigator reveals only the essence of the first order, after which stand points of higher orders. Having investigated only the structure of a system and the nature of its elements, it is possible to get to know the laws of functioning completely. At the same time the transfer to a substrate-structural investigation is necessary in order to remove the abstract nature of the functional approach and obtain concise conclusions.

However, the statistical nature of the connection between structure and functions has not only a negative value. It at the same time indicates that one and the same function can be reproduced with the help of a whole series of nonidentical structures. This enlarges the boundaries of applicability of functional models in comparison with structural and it involves the important conclusion about the existence of several varieties of structures of a control system, capable of performing the same function accurately. Without dwelling on the problem of simulation of psychic functions in a computer, it must be noted that this fact must be considered in the solution of organizational problems. It happens that one or another variety of structure of any military organization (centralized, with subordination on a vertical line, hierarchical, and so on) is assigned an independent value, while priority belongs not to structure,

but to function. A structure is selected from a class which allows such functioning, basically on considerations of an organizational-technical order.

Thus the specific nature of cybernetic simulation is that this is simulation of complex systems, it is dynamic and functional. These features led to the fact that in recent years a cybernetic simulation is finding increasingly wider utilization in the training of troops, in the practice of control of troops, and especially in military-scientific investigations.

In order to perceptively apply simulation as a method of military-scientific investigation, it is necessary to explain its *theoretical-cognitive role*, i.e., to define what place this method occupies in knowledge, and what are its functions and possibilities. Let us begin with the question: is simulation a method of *logical* perception or an *empirical* method? On one hand simulation comes forward in the capacity of a certain assistant in the practical check of the results of a theoretical investigation. For example, during a check of hypotheses and theoretical calculations about the possible course of a battle or operation in a rocket-nuclear war a model trial (in the form of maneuvers, command-staff studies, or in the form of an electronic model in a computer) is the criterion of likelihood and suitability of these hypotheses. In this case simulation comes forward as a *practical-empirical* method of knowledge. On the other hand, simulation appears as a method for the theoretical solution of practical assignments. Really, if instead of the expensive and dangerous tests of actual models of a weapon and battle equipment an investigation of mathematical or electronic models is conducted, then this is an unconditional replacement of an empirical check by a theoretical investigation. In this case simulation becomes a *logical-theoretical* method of an investigation. The logical-empirical duality of simulation is clearly manifested in the fact that even in the case of purely mental simulation this method does not lose the criteria of empirical perception, since operating with a mental model bears the nature of an experiment.

Simulation, being a specific method of perception, occupies an intermediate place between purely logical and empirical methods and comes forward in the capacity of a binding link between theory and practice, between sensual and logical perception. For these reasons some authors call simulation a *logical-empirical* (or empirical-logical) method of perception.

The question can arise: how is simulation correlated with other methods of perception? It is known that there exists, first of all, a universal method of perception — materialist dialectics, coming forward in the capacity of a general-philosophical base for any other methods of perception. In the second place there are *general-logical* methods, such as abstracting, analysis, synthesis, induction, deduction, and the method of conclusion by analogy, in accordance with which people form any judgments, conclusions, and proofs. Thirdly, *general-scientific* methods have been developed, such as observation, experiment, and formalization. Finally, an enormous quantity of *highly specialized* methods are known which are applied in particular concrete sciences.

The category of general-philosophical methods does not include simulation (although materialist dialectics in its constructions also sometimes resorts to a mental simulation, for example, a spiral in the law of negation of negation). At the same time it is not a highly-specialized method of any one (or even several) particular sciences, since it is applied everywhere. This means that the assignment is to examine the interdependence of a simulation with general-logical and general-scientific methods.

For this purpose we will follow the process of simulation. The selection or construction of a model begins with *observation* of the object of simulation and a *comparison* of it with other objects, which can serve as its models. This requires some degree of *abstraction* from the practical features of the object and model[1], and the

[1]It is remarkable, that N. Wiener and A. Rosenblueth consider abstracting in an indissoluble bond with simulation: "Abstracting consists of the replacement of a certain part of the world by the appropriate, but simpler structure, which is viewed as its model." A. Rosenblueth and N. Wiener. The role of models in sciences "Philosophy of Science," 1945, No. 4, page 316.

determination of the necessary degree of isomorphism proposes the utilization of the method of *induction*. Then the investigation of the model begins. It has the nature of *observation* and *experiment*. In this case for obtaining a quantitative result they resort to *formalization* of the connections and relationships of the investigated quantities, whereupon the model undergoes a logical-mathematical, basically *deductive* investigation. The process of the transfer of knowledge from the model to the object bears the nature of *interpretation* of knowledge obtained and it proposes the utilization of a *conclusion by analogy* and the *concrete definition* of the results of the investigation.

As we see, in the process of simulation all the general-logical and general-scientific methods are used, which makes it possible to call simulation a *synthetic general-scientific method of perception*.

The cognitive functions of models are very diverse, however, the main criterion by which they should be classified is the information criterion: which model does more accurately what it is possible to do with information. This is as if a question about the "cognitive efficiency" of the model. Therefore it is expedient to consider the cognitive functions of models in the following order: a) the function of storage of information, b) the function of coding the information and c) the function of obtaining new information. It is obvious that practical models in series or even simultaneously execute all these functions, however at each given moment and in the given relationship the main thing is any one of these functions. Such a classification, in spite of conditionality, can be sufficiently sequential.[1]

The class of models, which execute the function of storage of information, include the models, in which the modeling subject fixes the information already known to it, in order to use it when needed or to transmit it to others in a convenient form for assimilation.

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[1]This classification refers only to information models. It does not embrace constructive-energetic models.

Models in the form of any kind of imitators, calculators, mechanical plotters, templates, matrices, rulers, nomograms, charts, and so on can be used in the capacity of auxiliary means in the course of a military-scientific investigation (for example, in the process of accumulation of statistical material or during the processing of results). However, the basic spheres of application of such models are the training of the troops and their combat activity.

Fixing models are used widely in the course of practical control of the troops. In headquarters and at command posts extensive use is made of maps, plans, diagrams, systematic tables, and also slide and other calculating rulers, matrices, patterns, and nomograms for determination of the radiation situation, calculation of the necessary quantity of forces and weapons, etc. In recent years in the headquarters they adopted digital and analog computers, the circuits and codes of which in a number of cases are also their own kind of fixing models.

Models are applied just as extensively in the sphere of control of weapons and combat equipment. They are incorporated in various models of combat equipment in the capacity of calculators or plotters. For example, in aviation optical and radar bombsights there are computational devices, into which the initial conditions and current data are fed, and which then, in the course of an aiming, model any quantity (velocity, angle) according to a known law of its change. Such a type of model can for a time replace the object or its surrounding environment. Let us say during tuning and checking of radio equipment the radio operators make extensive use of generators of standard signals and imitators. The electronic models, fixing the information about the object of control, are included in the circuits of self-tuning automatic systems of control.

Models belonging to the class of fixing find wide utilization in the process of training of the troops. They imitate the objects and processes being studied and they also serve as the means of illustration of these or those situations of a training course. They play a part in didactic manuals, intended for facilitating the

understanding and mastering of material being presented. They are used in instructions on ballistics, aerodynamics, and other military-technical disciplines. The fixing models utilized for training include maneuvers, tactical studies on site, games on maps, and command-staff studies (if they are undertaken not for military-scientific but namely for training purposes). Here one should include the multiple trainers used in the training of fliers, navigators, radar operators, driver-mechanics, etc. Fixing models can also be included in the capacity of components in the composition of learning machines of various types.

The following function of models is the function of coding of information. It is necessary to resort to coding with the help of models in many cases. First of all this is done if *approximation* is necessary — the simplified, approximate expression of features, connections and relationships of the investigated system. From the point of view of the information theory the operation of approximation is a variety of coding by consolidation. Approximation serves as the means for the exposure of the most significant aspects of an object, and also as the means of "adjustment" of a practical system under an already existing mathematical or logical apparatus for the purpose of its further investigation.

Another case of coding information with the help of models is *interpretation*. For example, with the help of an abstract theory formal results are obtained which are general for a broad class of phenomena, let us say for all control systems. In this case the system of control, selected or built in the capacity of a model, is intended to give to abstract results a concrete physical meaning and to verify the conclusions of the theory. Thus, as the interpreting model for the checking of a mathematical investigation of a battle of operation one can use any concrete, most typical battle or operation, taken from the history of military art.

Also connected with the coding of information is the utilization of models in the capacity of *translators*, i.e., the means of reformulation of theories, hypotheses, or missions into terms of a more

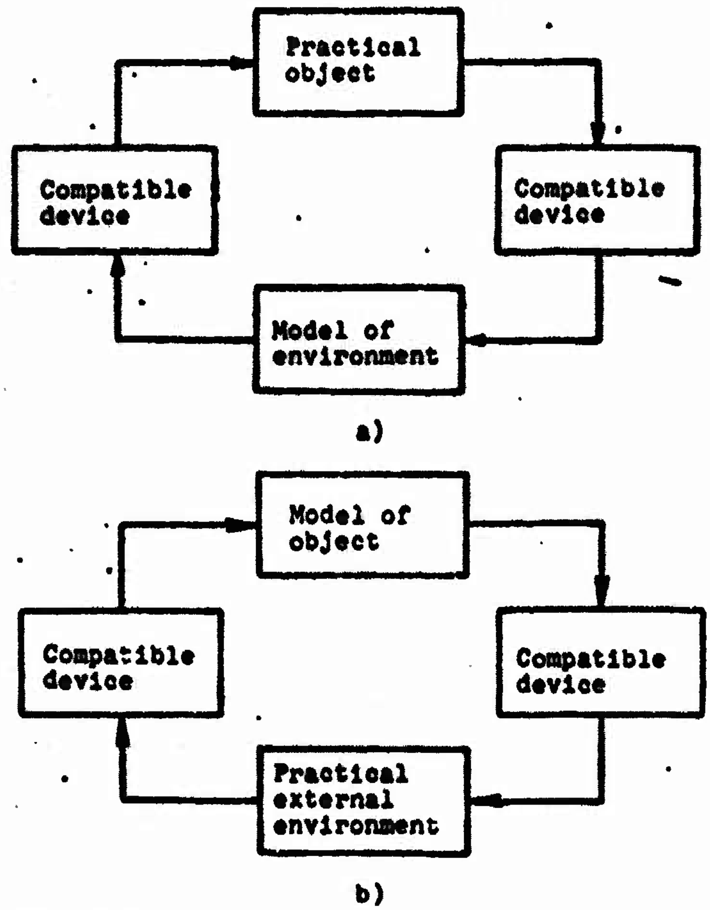

Fig. 3.3.

customary or more developed language. Here one should include the construction of formal-logical and mathematical models of real objects, with the help of which an assignment is translated into the language of mathematics and mathematical logic, and also the transfer of an assignment from a less powerful to more powerful logical-mathematical system, in which it can be resolved. Such a transfer is equivalent to the construction of a logical model, to the homomorphic structure of connections and relations which are fixed in the assignment.

Translation is also necessary for the transfer of an assignment to a more intelligible language or for ensuring clarity. For example,

mechanical models of electromagnetic phenomena proposed by Maxwell played mainly the role of translators to the language of mechanics which was more customary at that time. In this case a model can become the means of explanation of the mechanism of functioning of an object, which borders on the acquisition of new knowledge. In all appearances, the problem of translation will require specific development in connection with the need for the transfer of operational-tactical assignments into the language of mathematics and of mathematical logic or the reverse transfer of the results of logical-mathematical investigation of an assignment into the language of the theory of military art.

With all the importance of the functions of storage and coding, the main cognitive function of simulation is the *obtaining of new information*. As reported in the press, the utilizaiton of electronic analog devices of the type EMU-5, EMU-8, and EMU-10 in investigations in the area of aviation technology and radar makes it possible to obtain important new results.

Even if the isomorphism of the object and model is established only hypothetically or when the experimenter consciously goes beyond the limits of the reliably established isomorphism, simulation can serve as the means for the advancement of new hypotheses, and also as the means for the substitution of the links of the theory which are still missing. If isomorphism has been established reliably, then a model makes it possible to obtain reliable information by means of a deductive conclusion. In this case the prediction of development, the foresignt of the future phases of the process, is possible. For example, having built an adequate model of a forthcoming or already begun air battle and having repeatedly shortened the scale of time, it is possible to forecast its outcome and on this basis purposefully influence the process of battle and take measures for the well-timed and complete utilization of its results. As we see, simulation does not give "second-class" information, but such which makes it possible to investigate the essence of an object, its quantitative and qualitative aspects, and to expose the laws controlling it.

Such, briefly, are the theoretical-cognitive functions of cybernetic models.

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The utilization of simulation in military affairs has a very ancient history. Models were used since olden times in the development of new forms of an armament, the development of methods for their utilization, in the training of troops, in the solving of organizational-staff and strategic problems, and also in the course of the theoretical and practical solution of tactical assignments. The range trials of mock-ups and prototypes of a weapon, the maneuvers of troops, sandbox exercises, and command-staff studies proved their effectiveness and are now considered as specific military methods of investigation and training.

However, all these types of simulation, along with indisputable advantages possess a number of deficiencies. Such models of combat actions as the operational map of the commander, plans, diagrams and tables reproduce basically the statics of events for specific days and hours. The change in situation is introduced into such models only by stages, which does not give the complete picture of development of combat actions. Sometimes because of this significant moments drop out and some favorable possibilities or dangerous tendencies remain hidden. In other words, with such a method of simulation the depth and quality of the analysis of the dynamics of battle depend completely on the experience and abilities of the commander, since the method itself helps him so little in this.

Maneuvers, exercises, and range trials, being conducted in natural time-spatial scales, as a rule are complex and expensive, which now and then pushes to conditionalities and simplifications, and there is no possibility to attract a large quantity of troops and combat equipment. All this does not allow the repeating of the experiment under conditions close to combat, and sometimes one is forced to make responsible decisions about rearmament, change in the

organizational structure of the troops, or a reexamination of operational-tactical views without a sufficiently reliable scientific basis.

One additional def. iency of traditional simulation consists of its inadequate methodological strictness. Inasmuch as the degree of isomorphism of a model and object is evaluated only intuitively, and the methods of transfer of information from the model to full-scale have not been discussed in particular, then sometimes it is difficult to be freed from subjective values. For example, such a problem can appear during the carrying out of command-staff studies or of map exercises.

The new stage of development and utilization of simulation in military affairs first of all is connected with the wide implementation of mathematical and electronic models. A mathematics and the computer made it possible to create functional models of complex dynamic systems in military-technical, operational-tactical, and strategic areas. However, it would be a crude simplification to represent the matter as if electronic models simply replaced the traditional models, and the exercises of troops and map exercises became obsolete. On the contrary, the essence of the new stage of development of simulation lies in the fact that a strictly scientific approach to the traditional forms of simulation is created — methodological bases, quantitative criteria, and a mathematical apparatus have been developed which makes it possible to avoid subjectivism and superficial judgments and to organize the exercises for troops, command-staff studies, and games as a strict scientific experiment.

First of all the new methods of simulation received propagation in the process of developing, testing, and investigating the combat effectiveness of armament. In order to assign to industry the tactical-technical requirements for a new technology or weapon, often it turns out to be necessary to build a model of the proposed, but still not existing conditions under which it will be applied. In

essence this was always done, but earlier these models frequently remained intuitive mental constructions. Now for this goal powerful electronic computers are used. In England, for example, for investigations in the area of guided missiles, aviation and antiaircraft defense the largest analog computer "Tridac" is used.

Plant, state and army trials of full-scale mock-ups, pilot models, and pilot series also are a variety of model investigation, success and authenticity of conclusions of which in many respects depend on its methodological strictness. In this case full-scale trials are often very expensive, dangerous, and can lead to the divulging of a secret; the launching of a rocket or a powerful explosion is now difficult to hide. Therefore now they strive to conduct as large a share of tests as possible on electronic models. As was reported in the press, the utilization of a computer of the type "Typhoon," the cost of which comprises 1.5 million dollars, allowed the American rocket builders in one of their investigations to economize 250 million dollars.

An important role is played by simulation in the development of systems "man-combat technology." For the quantitative investigation of such systems a mathematical model of man is constructed, with the help of which the best conditions of his conformity with a machine are cleared up. Of specific interest in this case are emergency situations, when mainly man is included in the work, for example, during the failure of the apparatus for automatic orientation of a spaceship. In aviation they frequently use mannequins. Thus, according to American journalists, for the testing of the American X-15 rocket aircraft a human-shaped robot was made which in a series of dangerous tests took the place of the pilot.

For the optimum agreement of the system "man-combat technology" it is also possible to use models which imitate the separate functions of behavior of man. In this case models can be built into the system constantly. For example, completely conceivable is the creation of specific automatic units which are turned on by the bioelectric

currents of man. These are taken from specific muscles or even directly from encephaloscopic sensors attached to the head. In essence, such automatic units will be models of the extremities of an operator, in some things excelling the original (mainly, in the quickness of reactions and the nature of the transitional process). A more comprehensive examination of the possibilities of simulation of human psychics is given in the following paragraph of this chapter.

Designing, testing, and the operation of combat technology is a unique sphere of utilization of models in military affairs. No less an important role belongs to simulation in the solving of strategic problems.

One of the decisive components of the military power of a country is its strategic potential. This potential is determined not only by the gross volume of production, but also by such factors as the capacity of industry to change over rapidly to military harmony, and also the capacity without a noticeable lowering of production to inflict a nuclear rocket strike and air strikes on an opponent. With an equal volume of production these indices will be higher, where the enterprises are better distributed over the territory of the country, if they have back-up enterprises, and along with specialization and cooperation the necessary independence of enterprises is ensured. The solution to a problem of such a kind, just as the composition of mobilization plans and the distribution of human resources, can be an important sphere of effective utilization of logical-mathematical and electronic models.

The greatest military interest lies in the full-scale, play, mathematical, and electronic models of combat actions. They find utilization in investigations, training, and the practice of control of troops in combat. Today military-historical investigations often are merged in their procedure with simulation. In investigating one or another type of combat or operation, the scientist selects from a multitude of battles the most characteristic one, avoids what is accidental and unessential, and considers the selected battle as

a full-scale model depicting the general features which are characteristic for the entire given type of combat or operation in general.

For game models it is characteristic that they reflect the active opposition of an opponent. Whether these models be sign or electronic, they always reflect the actions of two controlling organs.

Electronic analog computers substantially extend the capabilities of a commander in the directing of combat. By means of the repeated checking of many variants of actions on a computer a commander can select the solution which is maximally close to optimum. By introducing incoming information in the process of battle and "playing out" each time the new terminations of battle while allowing for the new information, a commander can constantly introduce the most expedient corrections into the initial solution. Ir the press it was reported that in the USA a special electronic device has been developed for the simulation of the work of the automated air defense system "Sage." This device is intended for the selection of the optimum variants of the actions of the system in the most complex cases, when simultaneously 150 targets are tracked and the mission of intercepting 75 of them is solved. According to the data of the foreign press, this device made it possible under conditions close to actual to develop optimum variants for the utilization of fighter aviation, rockets and the "Bomarc" interceptor missile.

The specific nature of the contemporary stage of development of military affairs consists of the rapid and radical breaking up of established methods and means of armed struggle. This attaches even greater importance to model investigations in all their forms. As is known, the final criterion of truth is practice. However, the practice of military affairs in peacetime is limited. Therefore to obtain a representation about scales, dynamics, and aftereffects of contemporary war under these conditions is possible only by means of a scientific investigation, moreover the role of a "quasi-practical" check, which determines the suitability or unsuitability of any operational-tactical views, methods, combat technology, and weapons,

rests upon simulation. One of the models of such a type was the excercise "Dnieper" which was conducted in 1967.

* * *

Let us sum up some of the points made in this section.

The development of cybernetics led to the wide introduction in all branches of military affairs of constructive-energetic and information models. Electronic computers and new methods of mathematical simulation allowed the creating of functional dynamic models of complex systems, including systems for the control of troops.

Simulation acquired specific value in military science. Here it comes forward as such a research method, when instead of directly investigating an object of knowledge as such, the perceptive subject selects or creates an auxiliary object-substitute, investigates it, and transfers the information obtained to the object-original.

Simulation should not and cannot replace all the other methods of military-scientific investigation. It displays its capabilities best of all when it is used in conjunction with other cognitive methods.

It is important to note that there are no phenomena of armed struggle, for the perception of which the method of simulation would be inapplicable. Every concrete model gives only a limited picture of a phenomenon, however, many models can reveal any aspect of a phenomenon and any of their totality. In this is manifested the general dialectics of the process of perception — the limitedness of each given step and its infinity on the whole.

2. The Problem of Simulation of Human Psychics

The problem of the simulation of human psychics is more familiar to the reader in the form of the question, "Can a machine think?"[1] However, such a formulation of a problem does not embrace its entire content and it pushes for monosyllabic answers - "yes" or "no." But indeed this problem least of all resembles a switch with two distinct positions, and the volume and content of the concepts "machine" and "thought" have not been determined clearly at all; they are historic and are connected with the specific stages of development of science. Therefore, besides the solution of the problem about the possibility of development of an absolute analog of a thinking brain, the investigation of this problem proposes, in the first place, the determination of paths and prospects of simulation of separate structures and functions of the brain, the nervous system, and the sense organs; in the second place, the clarification not only of technical possibilities, but also of social, economic, military, and scientific needs for the development of such models; thirdly, it assumes the investigation of the problem - in proportion to the perfection of such models will there be a change in the methods of matching man and technology in various automated systems and on different levels of psychophysiological and intellectual loads; and it also includes the question, how will the concept "machine," "thought," "consciousness," and "psychics" be developed.

In other words, this problem is not reduced to merely semi-imaginative reasonings about the distant future, let us say about the possibility or impossibility of creation of an "electric super military leaders," able to take on the entire leadership of war, and also of fully automated, or, as it is said in the West, "uninhabited" combat machines. This investigation is called upon first of all to

[1]See N. Weiner. The machine is cleverer than creator, appendix to the book "Cybernetics ..."; A. Turing. Can a machine think? Fizmatgiz, 1960; W. Ross Ashby. What is an intelligent machine? Collection "Possible and impossible in cybernetics." Publishing House AN USSR, 1963.

define the technical politics in the area of perfection of practical systems "man - combat technology" and automatized systems for the control of troops: in which direction is the development of brain-like systems going, what can be expected from them in the nearest and the more distant future, how stemming from this to distribute duties between man and an automatic device in the systems of control of an aircraft, a ship, a rocket, or an air defense system?

The problem of the relationship of a cybernetic machine and the human brain is of serious sociological, ideological, and methodological interest.

The *social* value of this problem lies in the fact that the future of development of automation depends on its solution. Automation influences the social and economic life of society. Actually, as reported by the British department of scientific-industrial investigations, after twenty years as a result of automation no less than 60% of all the workers of capitalist countries will lose their jobs. If the possibility of the development of thinking machine is practical, then according to N. Wiener this "will cause unemployment, in comparison with which the contemporary drop in productions and even the crisis of the 30's will seem like a pleasant joke."[1] He considers that under capitalism this will lead to the depreciation of human labor and the intensification of exploitation: a thinking machine "is the exact equivalent of slave labor. Any labor which competes with slave labor should accept the economic conditions of slave labor."[2]

The social aftereffects of this would be such that many bourgeois sociologists prefer not even to speak about them. The English mathematician A. Turing called such a position an "ostrich." Its supporters consider that machines will not think, because "the aftereffects of machine thinking would be too terrible."[3]

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[1] N. Wiener. Cybernetics and society, page 166.

[2] Idem.

[3] A. Turing. Can a machine think?. page 34.

For a socialist society the development and utilization of thinking machines, if it is possible, does not present the threat of economic or moral shocks, since all the processes here are not subjected to the elements, they are planned and controlled on a scientific basis. But this does not lower, but strengthens our interest in the problem: in order to control it is necessary to know tendencies and outlooks, including those rather distant.

The philosophic-ideological value of this problem consists of the fact that it is closely bound with the basic question of philosophy. It is known that the basic question of any philosophy the classics of Marxism name as a question about the relationship of matter and consciousness. Its solution divides all philosophers into materialists and idealists.

The knowledge that material is primary and consciousness second is the fundamental knowledge of the history of human thought. Long before the appearance of cybernetics science had convincing proofs of the correctness of the materialistic solution to the basic question of philosoply. However, then man in his practical activity still had not created anything that even remotely reminded one of a thinking brain. The criterion of truth, as is known, is practice. The possibility of the practical simulation of psychic processes in such a material system as an electronic computer is a valuable direct proof of the validity of materialism.

The basic question of philosophy has a second side: is human consciousness able to correctly reflect the surrounding world, to perceive it? In this plan the question of the development of the machines, which are similar in structure and function to the human brain - this is a question about the possibility of perception by humanity of the mysteries of the most complex material organization - the human brain. The problem of the simulation of a thinking brain and the related problems of self-programming, self-organization, and self-reproduction of machines are receiving an important ideological sounding. They are important also as the source of new concepts for the further development of materialist philosophy, and as weighty

scientific arguments in the ideological struggle with idealism and religion.[1]

It is truth, a basic assumption exists, that the joint action of a series of laws of nature, society and thought can make impossible the complete simulation of a thinking brain. This must be considered. However, one cannot recognize as correct the point of view that the problem of the possibility of the reproduction of thought in connection with this should not be discussed. In our view, rejection of discussion would mean withdrawal from a sharp and important ideological problem, which would lead to passive defensive tactics in the ideological struggle, to a late "reacting" to the falling out of reactionary bourgeois philosophy instead of the well-timed dialectic-materialistic development of new problems.

The *methodological* value of simulation of human psychics is that it plays an important role in determining the fundamental possibilities of perfection of cybernetic devices.

In the course of planning of scientific investigations contradiction appears, for the resolution of which prior to the beginning of work it is necessary to guess its result at least approximately. It is obvious that science cannot be planned as timber cutting. The more unexpected the result, the more valuable it is. However, a single-minded experiment is more effective than a random search. Therefore during planning it is necessary to know what can and what cannot, because of the fundamental laws of nature, be expected from a given science. But such laws, which reliably determine the possibilities of a science, are established when it attains maturity. But the planning of a search is urgent namely for the young branches of science. Therefore scientists have no other outlet, besides

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[1]Concerning the atheistic value of cybernetics see Yu. Antomonov and V. Kazakovtsev. Cybernetics - anti-religion, 1964; S. Shalyutin. Cybernetics and religion, 1964.

predicting the result on the strength of its *ideology*.[1] In . case the role of the ideological position of the scientist in the selection of the direction of investigations proves to be decisive.

Actually, for a supporter of religious or objective-idealistic views the very posing of the question of the possibility of simulation of intellect is blasphemous. On the contrary, for those who consciously or spontaneously stood on positions of materialism, the posing of the question about the possibility of development of a thinking machine was completely natural. As is known, N. Wiener, J. Neumann, A. Turing and W. Ross Ashby stood on materialist positions on this question. Therefore they cam orward as initiators of the discussion about thinking machines in wor.. science.[2]

In this way, the heuristic value of a materialist approach is that it forces one to think about a problem, the posing of which is disputed by religious-idealist philosophy. However this does not at all mean that, having posed a question, dialectical materialism immediately predetermined an answer to it. Opinion, being our philosophy inasmuch as it is Marxist, is bound to give the immediate

[1]In a specific meaning the problem of simulation of intellect is philosophical inasmuch as it still is not solved in a natural-science plan. L. B. Bazhenov writes: "If we already had the devices which reproduce in a rather complete volume the functions of thought, or, conversely, if it is strictly scientifically proven, that such devices are impossible, then there would be no philosophical problem in general. But namely because this question is still not solved and one cannot speak with a hundred percent assurance that it will be solved subsequently, discussion on the methodological, philosophical plan for the outlook of its solution becomes especially urgent" (The Philosophy of Natural Science. First edition. Politizdat, 1966, page 361-326).

[2]The views of Wiener on the relationship of material and consciousness are rather clearly delineated in the following statement: "Cybernetics assumes, that the structure of a machine or of an organism is an index of their ability to complete an assignment. The fact that the mechanical rigidity of an insect limits its intellect, while the mechanical flexibility of a human entity ensures its almost infinite intellectual development, agree wel. from the point of view of the author of the given book" (Cybernetics and society, page 67-68).

final solutions to any problems erroneously. Marxist philosophy never attempted to assume the role of a master key, capable of instantly opening any scientific mysteries, for the penetration of which the "usual" sciences would spend years. And this is not its assignment at all. It should serve as the methodology of concrete sciences, shape the ideology of the scientist and thus to determine the most general basic positions of an investigation, prompt the effective methods of perception, and, finally, give an ideological and social value to the results of investigation. But it cannot and should not foretell or postulate the answers, which can be obtained only as a result of concrete investigations.

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To avoid ambiguity it is necessary to clearly demarcate, on the one hand, the present-day practical possibilities of the perfection of machines and, on the other, fundamental, maximally attainable possibilities. The practical possibilities of the perfection of cybernetic devices are determined by the currently achieved level of development of the theory of programming and the technology of electronic machine construction. These possibilities are concrete, specific for each given stage of the development of cybernetics, but they are constantly expanded during the transition from stage to stage. In a practical counterbalance the fundamental possibilities do not depend on transient factors. They are determined by the general laws of nature, society, and thought. There are also such limiting possibilities, to go beyond the boundaries of which without a supernatural "miracle" is impossible just as it is impossible, for example, to build an eternal engine.

Practical possibilities indicate what is accessible today, and fundamental - what is accessible during the unlimited development of science and technology. Today, for example, it is still not possible to guarantee the necessary weight, overall dimensions, and reliability of apparatus for the simulation of a brain, many processes which take place in the brain have not been investigated, and, consequently, what actually should be simulated is not known.

But neurophysiology, psychology, and radio-electronics are going forward, and present-day limitations will be forgotten tomorrow.

In solving the question about fundamental potentialities one cannot advance in the capacity of a limiting factor any present-day difficulty. However such a kind of error is not a rarity. For example, Professor Yu. P. Frolov in 1960 wrote the problem of modeling of a brain is unsolvable because it is hardly possible to decrease the overall sizes of electonic device so in order that they become suitable for the construction of brain systems.[1] In this case the author originated from the overall sizes of radio tubes and parts at the end of the 50's. The development of micromodules and film and printed circuits led to a decrease in the overall sizes by two or three orders, and ahead - new promises. For example, I. A. Poletayev writes about this, "what elements will arrive to replace contemporary radio tubes, transistors, magnetic and dielectric cells, conductors, and contacts? One can only dream and imagine about this."

"They may be waveguide devices, which operate with waves with a length of centimeters, millimeters, fractions of a millimeter, or with light waves. Perhaps there will be living cells, which cybernetic-biologists are beginning to rear in a nutrient medium in an assigned scheme with specialized functions. Perhaps this will be quantum-degenerated complex crystals, frozen in a cryostat almost to absolute zero, with a noncyclic structure (complex and the most complex molecules), able to endure isomeric transitions in accordance with arriving signals. Perhaps this will be something yet for which we do not know a name ... ."[2]

Some authors, including B. S. Ukraintsev, expressed the opinion that the modeling of a thinking brain would be impossible due to the low reliability of "capacitors, resistances, inductances, electrical

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[1]See Yu. P. Frolov. The brain and labor. Medgiz, 1960, page 179.

[2]I. A. Poletayev. Signal, page 382-383.

circuits, contacts (soldered or welded), etc., etc."[1] However, the theory of a reliability by strict mathematical methods proved that in principle from unreliable elements it is possible to create a system with any prescribed reliability.[2] Moreover it is important to take into account that the brain of man is a reliable arrangement made up of unreliable elements. During the course of life a renewal of "sickened" neurons does not take place, but the reliability of the brain is ensured because of the redundancy of organization - duplicating, a reserve and "alternate paths," which after a certain time after illness are put into order as a result of adaptation and training.[3] It is very probable that the reliability of a model in proportion to its substrate and structural perfection will automatically approach the reliability of the original.

Some authors point out that a brain consists of $1.5 \cdot 10^{10}$ complex nerve cells, which for the modeling of each tens (or even hundreds) of transistors are necessary. Based on their calculations even by "disarming" the whole radio electronic industry of the world, the necessary quantity of semiconductor devices could not be collected today. But this also is not a fundamental, but only a temporary limitation, just as the previous one connected with the present-day level of a electronic machine construction.

What was said in the previous paragraphs refers to substrate-structural designing of brain-like models - to the selection of circuit elements, their reliability, nature and type of bonds between them, etc. As a rule, the misunderstandings which appear because of the mixing of fundamental and practical possibilities in this area solve themselves relatively simply. More complex is the situation when it

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[1]B. S. Ukraintsev. About the possibility of cybernetics in the light of the features of depicting matter. Collection "The philosophical questions of cybernetics," page 128.

[2]See E. Mur, C. Shannon. Reliable systems from unreliable relays. "Cybernetic collection," 1960, No. 1.

[3]E. A. Asratyan, P. V. Simonov. Reliability of the brain. Publishing House AN USSR, 1963.

concerns the modeling of the functions of the brain - the psychic mechanisms of human acts, their algorithmic description and programming the behavior of the machine-model. In a number of foreign and Russian works concrete, frequently rather narrow functions are pointed out which allegedly are inaccessible in principle to a machine. For example, in the book by P. Kossa "Cybernetics" a whole list is given of things "that a machine cannot reproduce."[1] The author writes that a machine cannot go out beyond the limits of predestination, it cannot be taught, it cannot execute a critical function, to pass over from concrete to abstract, to devise, etc. On some of these questions it follows that it is obvious to think seriously. But not ten years has passed from the day of the writing of the book, but this list has very significantly "thinned." And again for the same reason: the place of fundamental limitations in it was unequally occupied by temporary present-day difficulties. Investigations in the area of logic, psychology, neurophysiology, and heuristic programming convince us that in the future new, unknown to us, principles of developing and programming of machines will inevitablity arise, which will introduce radical changes into the representation about their possibilities.

In discussing the problem about the possibilities of cybernetic machines, one ought to remember the situation of dialectical materialism, that possibility, before it turns into reality, passes through various stages. Initially it appears as an abstract possibility and even for its realization the necessary conditions are still not present. Sometimes it remains an imaginary, apparent possibility, behind which the fundamental impossibility hides itself. Most frequently this takes place because the joint reason causing the analyzable phenomenon is insufficiently known, and only some specific reasons are known. In that case the transition from an abstract analysis to concrete denies this possibility. For example, in the theory of algorithms, in order to not be limited by its

[1]P. Kossa. Cybernetics. Pub. House for foreign literature, 1958, page 111.

present-day level of the development of technology, sometimes they digress from practical possibilities and resort to the abstraction of potential feasability.[1]

Some authors, in proving the possibility of development of thinking machines, satisfy themselves by a reference to any one isolated aspect of the matter, for example, to the constructional practicability of a brain-like structure, to the potential possibility of an algorithmic description of any conceived form of behavior of man, to the unlimited capacity of a machine for learing and perfection of codes, but here the biological, psychological, social, and other factors of the problem are not considered. Nevertheless the action of the regularities, connected with the characteristics of the social-historic process - the formation of consciousness, the development of productive forces and industrial relations, and finally, some regularities of a moral-ethical order (for example, those which forced an end to the destruction of dolphins), can bring to nothing any technical possibilities.

Sometimes the limitations connected with our subjective ignorance and the limitations which originate from the laws of nature are mixed up. Frequently it is possible to hear that creative thought and human emotions in principle are unique. However, the successes of psychologists in the area of the heuristic-science concerning creative thought and the investigation of the information nature of emotions testify to the opposite.

If we have in mind the complete reconstruction of human psychics, besides the reconstruction of a nonmental or mathematical, but a material, i.e., in the form of a system which possesses another origin besides man, but is able to think, feel and express a will, then the future of modeling are apparently such.

Current computers for this purpose are unsuitable in principle. For their work these machines require exact programming on the basis

[1]See Philosophical Encyclopedia, Vol. 1, The article "Algorithm."

of the apparatus of mathematical logic, which is a contemporary step in the development of formal logic and it describes the processes of a rational-logical step of human thought. It operates already with ready, formulated concepts and it does rot pose a question about how these concepts are formed. Therefore a contemporary machine is a "dependant" of the human mind, it enters work only when it "is loaned" in ready form the formalized result of human knowledge. The process of modeling the cognitive activity begins here from the middle, and it is difficult to expect that such a conservative system as a contemporary computer would allow the filling in of the missing links of a model. Therefore the attempt to construct directly the assemblies which possess the ready features of developed psychics, and "to make up" from them a brain-like system hardly will lead to the successful solution of the problem. Most likely success will be connected with the utilization of self-adjusting, self-programming, and self-developing systems.

In all probability the first problem will be the development of a material structure which possesses a complexity of the same order as the complexity of the human brain. A simpler system is hardly suitable for this purpose. The futility of the attempts to train higher mammals specifically to human forms of behavior shows, that their brain, consisting of 3-5 billion neurons, is primitive for this purpose. In order that the organization of the system would not limit the possibilities of simulation, it must in all its complexity approach the human brain ($1.5 \cdot 10^{10}$ elements, similar to a neuron, appropriate reliability, the presence of inputs which are close in characteristics to the sense organs of a man, etc.). To do this is not very simple.

In considering this problem, A. Turing indicates that in essence, it is decomposed to two: 1) to create a device, the degree of organization of which would be of the same order as the degree of organization of the brain; 2) to impart to the machine the initial information which corresponds to that which is transmitted by inheritance. The first part of assignment, in his opinion, is simpler than the second: "Progress in engineering is also necessary,

however, it is highly improbable, that (fundamental - V. B.) a difficulty originates from this side. The problem lies mainly in programming."[1]

However, even the assignment of programming hereditary informatio in the opinion of Turing, is solvable. "Our claculation," he writes, "consists of the fact that the mechanism of the brain of a child is so simple that a device similar to it can be easily programmed."[2] It seems to us that Turing somewhat simplifies the problem. We still know very little about the structure and nature of hereditary information, and that which we know is still inaccessibl for modeling by contemporary technology. In comparing the brain of a child with the brain of an adult it can be said that "the brain of a child in a certain respect is similar to a notebook which we buy in a kiosk: an entirely small mechanism and very much that is pure pater."[3] But this is only in comparison with an adult brain, in an absolute sense this "mechanism" is extremely compound: in each single act of perception of a child in an abbreviated and converted form the entire historical process of the making of man is reproduced. In this way, to program hereditary information means in essence to present in a coded form the regularities of development of humanity. Even the very apparatus of programming is still weak for the solution of such a complex assignment.

If this problem is solvable, then a system will be obtained which models the state of biological need and the susceptibility to learning which is growing on its base. As is known, contemporary machines do not have their own internal need for existence. Machines which are called self-organizing, self-adjusting, and so on, correspond to their name only conditionally: self-development, i.e., a development because of an internal need, is lacking in them.

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[1]A. Turing. Can a machine think?, page 51.

[2]A. Turing. Can a machine think?, page 52.

[3]Idem.

The machine, which possesses the internal need for development, susceptibility to learning, and a rather large memory, A. Turing calls a "machine-child." He considers that such a machine should "be provided ... with good organs of sense, and then learn to understand and speak in English. In this case the machine can be trained as a child."[1]

Here there are also serious difficulties. How to teach a machine to react to words and to pronouce them more or less clearly? It can be done with the help of contemporary computers. The basic difficulty is to teach the machine to understand words. It is true that Ashby considers that to create new concepts is basically simple: with the appropriate interpretation concepts are the results of the work of an electronic circuit, connected with any kaleidoscope - with a noise tube or even with the viscera of a sheep. But the whole essence here is included in the words "with the appropriate interpretation," since realization and interpretation of results still are accessible only to man and the essence of these processes still has not been clarified to the end.

In the final analysis everything rests on the need for the simulation of consciousness, which, as is known, is not only a property of highly organized material, but is also the product of the social-historical development of humanity. This means that the next assignment is to model a social environment which is rather rich in an intellectual respect or to attempt to include a "machine-child" in the existing social environment. The second path seems improbable, since a machine is a weapon and not the subject of labor. An attempt to change its position in the system of productive forces and industrial relations all the more so in the system of all public relations, will unavoidably bear the features of artificiality and, in essence, will be reduced in the simulation of a social environment.

The creation of an information model of a social environment is

[1]Idem, page 58.

an assignment of such complexity, with which contemporary science has still not encountered. Human relations are extremely complex, and the present logic-mathematical apparatus is still too weak to describe them. However, the social environments and its pressure on the shaping of consciousness of an individual are natural and cognizable, and therefore there is no basis for considering that its simulation will always be impossible.

From everything stated above the following conclusions can be made. Today knowledge about the structure and functions of the brain, methods and apparatus for their logic-mathematical description, and the technology of electronic machine construction still do not allow any close approach to the complete solution to this problem. In this case the basic difficulty - the difficulty of description and simulation of the social environment in which consciousness appears - is still ahead. However, among those presently known laws of nature, society, and though there are none which irrefutably indicate the impossibility of the development of such machines. Apparently one must originate from in organizing the scientific search in this direction.

However, any possibility for society, including technical, remains unrealized if none of the economic, social, or military needs for its realization exist. Therefore, in addition to the analysis of technical and other possibilities, one should still study the question of whether or not the interest of people in the creation of such machines exists. Otherwise society will find better utilization of its forces and means.

Considering the tendencies for the automation of production and the armed forces, it is not difficult to notice that the trend to replace man by a machine is manifested only at a lower level. In complex systems the assignment of automation is to supplement man with a machine, matching them in a single complex in order to mutually compensate the deficiencies and emphasize the advantages of each other. A machine which possesses in accuracy the same deficiencies and weaknesses as man can become an expensive, but a useless adornment of the system. The leading tendency of the

development of electronic and other machines for processing information in the future remains not a simple repetition, but namely the supplementing of the features of human psychics.

However, this addition bears a very dialectic nature: in order to supplement thought at some level, a machine must be similar to it namely at this level. In this way supplementing itself is connected with simulation, and the trend for more effective matching of the machine and the brain requires increasingly more complete repetition of the features of the second in the first.

Futhermore, in industry, science, technology and military affairs such assignments exist, for the solution of which as complete a repetition as possible of the features of psychics is directly necessary. In industry and technology an analog of the brain is necessary at harmful productions, underground works, uranium mines, during emergencies and rescue operations, and also during the dangerous testing of atomic reactors, new models of aircraft, piloted space objects, and in many other cases when the presence of man not only does not remove technical difficulties, but generates new ones. For example, the presence of man on a spaceship leads to the need for the solution of the most complex problem of subsistence, radiation protection, incomparably increases the requirements for the reliability of equipment, and leads to compulsory systems for return and landing. Such an expensive tab sometimes makes it necessary to look in on the work of one or another system not with the help of telemetry, but with so-called "human eyes."

Models of the brain are also necessary for investigations in the areas of neurophysiology, psychology, logics, linguistics, education, and a whole series of other sciences. The value of such models lies in the fact that with their help it is possible to investigate any pathology, dangerous disorders and their causes - here indeed it is possible to vary conditions without fearing a sad outcome. In this way it is possible to find the most effective means of therapy, education, training, and development of abilities. Models of this type will become very useful during the investigation of optimum

conditions for the matching of man and technology in a situation of increased nervous stress, induced by danger, and also for the development of algorithms of behavior of man in emergency situations.

It is considered that such a kind of model will find utilization in military affairs, for example, for increasing the effectiveness of pilotless reconnaissance aircraft in the processing of non-formalized information, in the control of combat machines in complex situations not envisioned by the program of conventional computers and, finally, for reducing the degree of danger to which people are subjected in a zone of high radiation.

It is possible to assume boldly that the scientists of all countries of the world will continue work in the area of simulation of a thinking brain, striving to pass from primitive particular to increasingly improved and complete models of psychics. In the press the thought was expressed that the army, which has the better machines of this class will gain serious supplemental military-technical advantages.

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In concluding the present section, dedicated to the discussion of the methodological problems of the simulation of human psychics, it is possible to make the following conclusions.

Inasmuch as in industry, science, technology, and military affairs the need exists for machines, reproducing the function of the brain, the nervous system, and the sense organs, then the need exists for the development of the methodological problems of such simulation. The role of philosophy in this area is not reduced to a monosyllabic answer to the question, is it possible to create a machine which completely repeats a thought. A philosophical investigation proposes the development of a basic ideological concept and an object, considering economic, social, and military factors, and it also includes the gnoseological analysis of basic concept and the development of methods of investigation.

In the solution of problems connected with the simulation of human psychics one ought to originate from a fundamental Marxist situation, that thought is the property of highly organized matter and the product of social-historical development. In the origin of consciousness and psychics there is nothing supernatural and unperceptible, and therefore there are no bases to assume that in the future the possibility will not arise for the artificial reproduction of thought in a system which is different from the human brain in origin. However, the difficulties on the way to this are extremely great, and until such simulation comes forward as an abstract possibility, which altogether will not contradict the basic laws of nature, society, and thought. In this case there are no guarantees that further investigation will not lead to the discovery of such concrete regularities or a combination of factors which will show that this is only an apparent possibility, incapable of turning into reality.

Hence our approach to the development and utilization of brain-like machines in control systems should be rather elastic and realistic. At each stage of development of science it is necessary to strive to completely use all its achievements for all possible perfection of a weapon, combat technology, and the systems for controlling them.

3. The Problem of the Logic-Mathematical Description of the Processes of Armed Struggle

In recent years stormy process of "mathematization" of military knowledge has been going on, moreover especially rapidly the mathematical apparatus and the quantitative methods of investigation are penetrating the theory of military art. Several interdependent reasons exist for this: the clearly expressed technical nature of contemporary transformations in military affairs, the need for optimization of the processes of control of a weapon and troops, and, finally, the need for the automation of control systems.

Present radical conversions in military affairs led to the fact that an exact quantitative prediction of the actions of troops

became a substantial part of the decision of a commander. The utilization of contemporary, in particular nuclear rocket, weapons increased the accuracy required of decisions. Estimated qualitative values now prove to be hardly effective, and often dangerous. The troops are now loaded down with electronic equipment, and for controlling it it is necessary to possess firmly the universal language of science - mathematics.

The high development of contemporary military art caused a trend to optimize the processes of control of the troops and weapons. But optimum control unlike control in general becomes possible only when there are not only qualitative expressions of general regularities, but also a strict quantitative description of bonds, relations, and interdependences inherent to the given phenomenon.

As concerns the automation of control of troops and weapons, then its fundamental possibilities depend on which bonds and relationships of armed struggle in principle can be described by a formal logic-mathematical apparatus and which of them by their very nature are nonformalizable. The fact is that the possibilities of formalization determine which and how much information can be introduced into omputer program, and, consequently, where they can be used.

It is true that assertions are encountered that machines will exist for which a program is not required. Be it thus, all difficulties connected with mathematization and programming may be bypassed. However, the concept, as if self-programming machines do not require a program, is based on the mixing of the concept of a program in general with that particular case of a program which takes place in devices with "program" (or command) control, for example in automatic lathes. As a rule, following the assertion mentioned above there should be a discussion about such methods of machine programming when the information, with the help of an algorithmic language, let us say the ALGOL-60, is input into a translator, and already the translator "makes" the program.[1]

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[1]See G. Bottenbrukh. The structure of ALGOL-60 and its utilizations. Publishing House of foreign literature, 1963.

In other cases they say that machines can be adapted to changing conditions, to learn, etc.

As we see, the supporters of this point of view consider as a program only the program of actions of a machine which is directly created by man, but the program of learning, self-adjusting, selection, and the creation of new programs they no longer consider as programs. But indeed even the process itself of development of a machine - this is not only a physical process, but also the process of transmission and conversion of information, and the main circuit of the machine is its structual program.

Machines, being created on the basis of principles currently known to science, will always require an algorithm. It is unimportant whether this is an algorithm of the direct solution of an assignment or an algorithm of search for the paths of a solution. The progress of cybernetic devices, which do not represent a complete copy of the brain, is found in direct dependence on capabilities of mathematical and formal-logic representation of processes and phenomena of armed struggle.

The aforesaid should not be understood as simplified, as if man must absolutely solve everything himself, and after that the machine will repeat the same accurately. The discussion is not about this. The program determines the "world" of the machine, its "universe," the horizons of its vision. But within the limits of these horizons it can find original paths of solution and show those aspects of the phenomena, about which the compilers of the programs did not suspect. This is possible because an algorithm is the product of human genius and it contains particles of this genius.

The problem of programming is not eliminated for machines which rather fully model psychics. Indeed man is not free from the certain program, which comprise the system of behavior developed by humanity and imparted to each individual by inheritance and in the process of education and training. Man enters an industrial relationship which does not depend on his will, uses the industrial skills,

which basically were obtained from preceding generations, and with deviations from the standards of morals and rights experiences the "regulating" pressure of society, etc. If man already has a program, then for the machine which is an analog of a man (at any level of its perfection), a program is all the more necessary. But to artificially create such a program is difficult: if a considerable part of the program of human behavior is formed unconsciously or only guessed intuitively, then in the programming of a model it is a must to be completely theoretically comprehended by the investigators.

In this way, any of the paths of perfection of the cybernetic devices being applied in the sphere of control of weapons, and in particular of troops, will lead to the problem of the logic-mathematical description of processes and phenomena of an armed struggle or to the question about the future of "mathematization" of the theory of military art.

* * *

Attempts to use mathematics for a description of an armed struggle and for the prediction of its development were observed already in the XVIIIth Century. They are connected with the names of G. Lloyd and D. Bulow. The first of them in his memoirs attempted to investigate the quantitative connection between various factors influencing the course and outcome of battle. D. Bulow continued the investigations started and substantially enlarged the sphere of utilization of mathematics in military art.

However, these investigations had serious deficiencies, and by the beginning of the XIXth Century they lost their value. According to Lloyd, war was divided into two sharply opposite sides: material factors, which can be described quantitatively and applied during their investigation of mathematics, and subjective factors, not lending themselves to mathematical description and not falling in any standards and rules. As concerns Bulow, then he not only did not overcome the deficiencies of the theory of Lloyd, but he aggravated them, detaching mathematical methods away from practical military art.

The next attempt to mathematize military art belongs to the English mathematician F. Lanchester. In his book "War and The Air Forces," published in 1916, he proposed equations, expressing the dependence of the losses of troops on their concentration during the application of various types of weapons. The attempt by Lanchester was also not very successful, since his equations considered only some of the factors influencing the outcome of battle, and that is why the practical utilization of this method often led to results which were very far from the truth.

Mathematical methods of investigation of battle actions received their widest utilization in the course of The Second World War, when in many countries of the world the best mathematicians were drawn into this work. During this period methods were developed for appraising the vulnerability of targets, methods for the investigation of the effectiveness of firing, and even a specific mathematical apparatus was developed for the analysis of conflicting situations which are so characteristic for an armed struggle.[1]

However, all this was only the prehistory of that vigorous process of mathematization of military knowledge which began in connection with the introduction of nuclear-rocket weapons, supersonic aviation, space means for combat, and electronic systems of control. Now mathematical methods of investigation penetrate literally everywhere.[2]

The introduction mathematical methods proceeds through the overcoming of objective and subjective difficulties, many of which bear a methodological and ideological nature.

Military science, as is known, is found "at the junction" of technical and social sciences and is intimately connected with both of them. Therefore the tendencies of development of these sciences

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[1]See F. Morz and D. Kimbell. The methods of investigation of operations. Publishing House "Sovetskoye Radio," 1956.

[2]See I. I. Anureyev and A. Ye. Tatarchenko. The utilization of mathematical methods in military affairs. Voyenizdat, 1967.

and of the disposition of various groups of scientists find their reflection in the area of military science. If the introduction of mathematics in the military-technical field and its utilization in the capacity of an auxiliary means in the theory and practice of military art for accounting for material factors of armed struggle do not encounter specific methodological difficulties, then its utilization in the capacity of a method for the description, simulation, and investigation of subjective, and in particular social, aspects of an armed struggle frequently causes distrust and even specific fears. Actually, as soon as the matter reaches a mathematical description and calculation of such factors as the moral spirit of troops, sympathy and antipathy of the local population, organizational abilities of commanders or the description of the regularities of motion and the outcome of war, then it is necessary to hear statements that these aspects of war in principle do not allow a mathematical description, mathematics allegedly never will be able to take into account the complex dialectics of an armed struggle, that this is only the domain of command intuition.

To overcome such difficulties means to sort out in detail the capabilities, tendencies, and outlooks for the mathematical description of all social phenomena in general. Then it will become clear what can, and what cannot be expected from mathematics in the sphere of armed struggle.

* * *

The need for mathematization of social sciences is determined mainly by the fact that the level of their development should correspond to the level and need for development of the object of investigation itself - a socialist society which entered the period of the building of communism. Communism as a higher social-economic formation proposes and a higher freedom to the members of society, and namely supremacy over the processes of social-historical development, optimum control of these processes, which naturally requires a strict quantitative description of the object of control and the process of its change.

At the same time the need for the mathematization of sciences flows out of the internal logic of the development of all contemporary science in general. V. I. Lenin more than half a century ago pointed out that from natural science to social sciences mighty current flows which is strengthened with each century. The mathematization of social science comes forward now as one of the means for the creation of a single language of science, the unification of its conceptual fund, necessary for the mutual enrichment of sciences and the "cross fertilization" of concepts. Many prominent scientists point out this process. For example, R. Oppenheimer wrote: "We begin to note, that the deep precipices, which up to recently were separating the various spheres of nature from one another, the precipices between the living and the dead, between physical and spiritual, looked insurmountable; these precipices are beginning to gradually step back under the strong pressure of tedious investigators."[1] N. Wiener expresses this thought still more sharply. He writes that "the division of science into various disciplines is no more than an administrative conditionality, necessary only for the convenience of distribution of forces and means."[2]

Contemporary science not only require the utilization of mathematics, but also it creates the practical possibility of its introduction into social science. On the one hand, these sciences themselves achieved such a degree of maturity, when the bonds and relations being studied by them were investigated in such detail, that they could be described mathematically. On the other hand, mathematicians developed the methods, really applicable for the investigation of such a complex object which is human society. The same processes also occur in military science.

The possibility and need for the utilization of mathematics in social science was pointed out by K. Marx. In a letter to F. Engels on 31 May 1873 he wrote: "I repeatedly attempted - for the analysis

[1]Cited in the book by M. Ruze "Robert Oppenheimer and the Atomic Bomb," Gospolitizdat, 1963, page 11.

[2]N Wiener. I - the mathematician. Pub. House "Nauka," 1964, page 166.

of crises - to compute these ups and downs (increase and decrease - editor) as incorrect curves and thought (and I still think that with adequately proven material this is possible) to deduce mathematically from this the main laws of crises."[1]

This statement contains important indications in principle. In the first place, from here it follows that the mathematical description of social phenomena in general, conflicting situations, which is economic competition under capitalism, and an armed struggle, in particular is completely possible. Moreover, the repeated attempts which were undertaken by Marx testify that he considered such a description of phenomena necessary for the further development of social science. The second indication by Marx is that for the mathematical description of social phenomena it is necessary to have "adequately proven material." Finally, the third indication by Marx is that a mathematical description makes it possible to reveal not simply some of the many regularities, but namely the "main laws" of complex social phenomena.

In connection with "mathematization" of military science a number of theoretical-cognitive questions arise: a) Why up to the present these methods have not found the proper distribution in the humanitarian sciences? b) Which social phenomena because of their nature in principle do not allow it? c) Is the contemporary mathematical apparatus in a condition to adequately reflect the bonds and relationships which are inherent to social processes? We will attempt to examine these questions briefly.

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Why up to now have not mathematical methods found application in social science? In order to reveal the main reason, one should first of all turn to the nature of the objects of investigation themselves.

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[1]K. Marx and F. Engels. Col. Vol. 33, page 72.

The type and complexity of a mathematical apparatus, suitable for a description of a given phenomenon, depend on the nature of the bonds and relationships and finally on the nature of the phenomenon itself. It is known that each thing has an endless number of bonds and relationships with its surrounding world. However, not all the bonds are equivalent. Some can prevail over others, and their action can be several orders stonger than that of the others. Furthermore the bonds can be stable or unstable, determine the essence of a process or only add to it this or that unessential part.

All phenomena and processes in the nature of their bonds and relationships in first approximation can be divided into two types: a) with a limited and practically small number of substantial stable bonds prevailing over all the remaining ones, and b) with a theoretically indinitely large number of uncorrelated bonds, which do not reveal a noticeable dominance over one another and determine the outcome of the process in its entire totality. A classic example of the first type of phenomena can be the movement of the planets of the solar system. In this process the dominant values are the masses of the planets, their orbital velocities and the distances between them and the sun. All the remaining relationships, determined by the form of the planets, the distribution of their masses relative to the centers of gravity, the properties of the atmosphere, the movement of meteorites, etc., are by many orders less significant. An example of phenomena of the second type can be the thermal motion of molecules of gas. Here the vector of velocity of each of the molecules is determined by a potentially endless number of approximately equal in value and weakly correlated bonds and relationships.

In the description of processes of first type a very effective means turns out to be differential and integral calculation, which makes it possible to establish exact individual or "regular" laws, for example, the laws of Newton and Kepler. In the description of processes of second type success is attained by using the apparatus of the theory of probabilities and mathematical statistics, making it possible to establish laws which are valid for the whole ensemble of events.

However, such a division of processes and phenomena into two types holds true only as a first approximation. The basic mass of practical processes does not possess such clearly delineated criteria of these classical types. Under specific conditions they even pass over from one to another. If we take a hypothetical planetary system, where the distances of the planets from the sun and between themselves are commensurable with the radii of the planets, then their orbits will be dependent to a greater degree on the distribution of mass of the planets relative to their centers, density, elasticity, the effect of flows, and even on the parameters of the atmosphere. In this case to convey the orbits of the planets with the help of the laws of Newton and Kepler either cannot be done at all or it will be a crude approximation. In this case it is possible to show only the probability characteristics: planet A at moment T with a probability P is found in the sphere of radius R, the center of which is preset by coordinates x, y, z.

The types of phenomena shown above are not divided absolutely and in the sense that in some respects the given phenomenon can come forward as regulated (so we will call the first type of phenomena) and in the others - as probable (these include the second type of phenomena). The thermal motion of molecules is not chaotic in all respects. Each molecule from collision to collision is moved rectilinearly and evenly at a rate which is determined by the reserve of energy obtained during the collision. This process is regulated. In another respect to the reserve of energy received by the molecules during collisions - this process is probable: it is possible only to say, that with a probability P the energy received during the given collision will be found within the limits $E \pm \Delta E$. But at the same time the average energy E, received by molecules over a large number of collisions, depends "in a regular way" on temperature T and pressure P. Analogous is the affair with the regularities of armed struggle: in some bonds and respect they come forward as regulated, and in others - as probable. Attempt at the separation of these regularities into two types based on the principle "either - or" or the enrollment of all phenomena into one of these types will hardly bring success.

The division of phenomena into regulated and probable is also relative because between them, if we present them as some poles on a scale of gradations, zones of phenomena are disposed, which can be called "regulating," moreover it is possible to outline a number of degrees of ordering depending on the attraction of the phenomenon to any pole. Let us take, for example, the motion of electrons over a conductor under the influence of the difference of electrical potentials. Initially let the difference of potentials be equal to zero. The process is purely probable: the electrons are found in chaotic thermal motion in the direction of all three spatial axes. In proportion to the building up of the difference of potentials the motion of electrons will be regulated more and more from the negative pole of the source to the positive. In this way, with a buildup of the dominance of one or a few factors the process is regulated. However, purely regulated phenomena do not exist: for this in the given example an endless difference of potentials would be necessary. And also purely chaotic processes do not exist. The electrons of a conductor, in addition to chaotic thermal motion, are also found in motion connected with the movement of the whole conductor (a convective current), for example, together with the rotation of the earth. Purely regulated and purely probable phenomena are certain heuristically justified scientific abstractions, idealizations which characterize the boundaries of the scale of gradations.

The laws of science reflect the laws of nature with a certain error which decreases in proportion to the development of the science. On each step of development of a science it is necessary to resort to simplifying assumptions. Those phenomena, which with a certain assumption can be idealized and reduced to one of the extreme cases, lend themselves more readily to a mathematical description. Therefore the mathematization of science goes more rapidly where the nature of the bonds is closer to "the flanks" of the scale of gradations, and it falls behind if the phenomena, conditionally speaking, are located "in the middle." That is, when there is a complex interlacing of bonds of various orders with low repetition, which allows the application of the statistical apparatus, and there is no stable dominance of a small number of bonds, which expose with

satisfactory approximation "regulated" laws. The more complex a phenomenon, the more frequently it happens that bonds, indifferent to a process under some conditions, gain the capability to influence it seriously in others. In this case the bonds acquire the nature of interdependences, they become polygonal and circular, they are correlated between each other, and the phenomena themselves do not possess a sufficient mass nature within the limits of one and the same qualitative state.

These are the main difficulties encountered during attempts to simplify the description of social phenomena. Idealization is carried out simpler, when it is dealing with lower forms of movement of matter and, convesely, it becomes very difficult in respect to higher. Therefore mathematics became a generally accepted language of mechanics already in the XVI-XVIIth Centuries, entered solidly into physics during the two subsequent centuries, and only now is beginning to penetrate biology and the social sciences.

In spite of the fact that the forces of a number of prominent mathematicians on the mathematical description of biological processes, are now directed the difficulties are so considerable, that the obtaining of strict expressions of basic biological regularities is an assignment which is not very close to solution. In the social phenomena the picture is complicated, since they are all expressed directly by conscious human activity. It is true, in the description of some processes (for example, the growth of a population) this direct expression proves to be more or less distant, but most frequently, in particular in the sphere of armed struggle, this is not so. Consciousness is not a simple reflex mechanism; the reaction of each man to change in external conditions proves to be unique, depending on his outlook. Therefore the classics of Marxism indicated the nature of the laws of social life, proves to be exclusively complex; these laws open a path through the chaos of randomness, coming forward only as a ruling tendency; these laws "by no means are iron, but, on the contrary, are very elastic ... ."[1]

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[1]K. Marx and F. Engels. Col. Vol. 19, page 3.

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Social phenomena, where the role of conscious human activity is relatively small, can be attributed to the category of self-regulating, however, the majority of processes in society are perceptively ordered by means of active human activity. Here is what G. A. Fedorov wrote about armed struggle: "To which type of processes does armed struggle refer: to regulated or chaotic? To both. An armed struggle represents processes, constantly being regulated by more general laws, by military organization, its system, and also by means of the leading and organizational activity of command personnel, beginning with the younger commanders and ending with the supreme high command.[1] At the same time each of the fighting sides strives by its strikes on enemy troops to disrupt the regularity of their actions, to disorganize them, to introduce chaos in them, which generates a multiple and various randomness in the course of armed struggle. [Translator's Note: End of quotation not indicated.]

[1]Marxism-Leninism on war and the army. 5th Edition. Vcyenizdat, 1968, page 359.

The phenomena of armed struggle include those which are most complex for a mathematical description, which namely explains the fact that mathematical equipment, suitable for a description of simpler phenomena, is still not always applicable in this area.

Attempts to mathematically express the basic laws of war have still not been crowned by success. One of the difficulties is a deficiency of statistical material: the mathematical description of a process is possible only in the case when there is a definite, sufficient for expansion of the law, repetition, which allows the observing of the outcome of events depending on being varied conditions within certain limits. In this case it is important that the conditions be changed under such limits at which the measure would not be disrupted and a qualitative change, excluding the possibility of a direct quantitative comparison, does not take place.

According to the data of the Swiss scientist Jean-Jacque Babelle over the last 5559 years there have been 14, 513 minor and major wars. At first sight this phenomenon is so mass, that the statistical treatment of material is permissible. However, these wars occurred in various periods of human history, during different social-economic formations, an unequal level of development of economics, science, technology, and military art; in them different weapons were used and the wars themselves differed essentially in their scales and political goals. All this led to serious changes in action of the objective regularities of movement and the outcome of wars, and, consequently, to important changes in the strategic and tactical principles of the conduct of war. Therefore the attempts at a direct comparison of the quantitative indices which characterize the wars of different periods for the purpose of exposing mathematically exact expression of the basic, general regularities which determine the course and outcome of any war, with the contemporary facilities of investigation prove to be unsuccessful. Such a comparison turns into a senseless operation with various quantitative values.

In the history of military art there were no periods of continuous stagnation, but some characteristics of an armed struggle

sometimes remained almost constant over a number of centuries. Thus, according to the data of Professor Major General of the Technical-Engineering Service G. I. Pokrovskiy, for 2500 years the area on which battle actions were deployed increased by no more than 10 times, but the density of combat formations during the same period decreased by approximately 10 times. As we see, the rate of change in these values was so insignificant that in many cases these values could be assumed constant without a great error. At the end of the past century vehicles for combat and electrical communication for control of troops were introduced, and in some five-seven decades the zone of armed struggle increased by 200 times, but density fell by 500 times. This was a deep qualitative jump, which led to the radical change in all quantitative correlations.[1]

Similar jumps are not a rarity in social phenomena, and that is why N. Wiener assumed that humanitarian sciences are a poor field for new mathematical methods. In substantiating this opinion he wrote, "the basic values having an influence on society... are determined by extraordinarily short statistical series.... For sufficient statistics of a society it is necessary to collect data for a prolonged period of time under essentially constant conditions.... Statistical series of long standing, composed under very variable conditions, give only an apparent, a false accuracy."[2]

In all validity the point of view of Wiener in this case is too pessimistic. The difficulties, of course, are not little, but in the end they are surmountable. In military affairs there is an area where already with the help of a contemporary mathematical apparatus it is possible to achieve a high effect. Thus in examining the regularities of an armed struggle on an operational-tactical scale, it is possible to see that engagements and operations possess a sufficient mass nature within the limits of one and the same qualitative condition of armament, battle technology, and military art,

[1]See G. I. Pokrovskiy. Science and technology in contemporary war. Voyenizdat, 1959, pages 9 and 10.

[2]N. Wiener. Cybernetics..., pages 40-41.

and that is why the application of quantitative methods in general, and methods of mathematical statistics in particular, here actually proves to be fruitful. Evidence of this are the serious successes of the practical application of the theory of investigation of operations.[1]

The mathematical investigation of battle actions in the period of the Second World War began in air defense [PVO], aviation, and fleet not only because this was necessary. Such a need existed in all the arms. Air defense, aviation, and the fleet became the object of such investigations earlier than the ground forces because their actions in a tactical respect were simpler, more alike, and more monotonic than combined-arms combat, in connection with which the conditions of armed struggle here prove to be sufficiently stationary for the quantitative comparison of a large number of single-quality events. Conversely, the large variety of conditions, and also the difficulties of input of data into an automated system for the processing of the information, connected with the low radar and television contrast of ground troops, essentially hamper mathematical investigations and the automation of control of combined-arms combat.

An analogous picture is observed in economic investigations. Considerably lighter concepts and methods of mathematics are introduced into concrete economic investigations, moreover predominantly there where the "tactics" are relatively simple, and, conversely, they enter with great difficulty into the custom investigators who are occupied in an analysis of the complex and sufficiently general problems of political economics.

In this way the basic factor which defines the level of development of mathematics, with the achievement of which becomes possible its introduction into various branches of military science, as we see is the complexity of the objects of investigation themselves.

[1]See F. Morz and D. Kimbell. The methods of investigation of operations; Ye. S. Venttsel'. Introduction into the investigation of operations. Pub. House "Sovetskoye Radio," 1964.

At the same time it is necessary that science itself - its conceptual fund, a logical structure and system of proofs - be prepared for the perception of mathematical methods, and the scientists who work in this area realize the need of mathematization and prepare themselves for the utilization of new methods.

What should be the mathematical apparatus, which will allow with the greatest degree of approximation to reality to describe the essential aspects of armed struggle? Most frequently it happens that if a problem allows mathematical formulation, then this leads to one or more differential equations. Therefore it may well be that the dynamics of an armed struggle be expressed by a system of such equations, moreover, most likely these will be nonlinear equations with variable coefficients.

Another possibility exists which seems more probable. The matter is that for the mathematical interpretation of new scientific representations frequently a new apparatus is created: the laws of Newton required a differential calculation, for operating with a time-spatial contiuum - a tensor calculation. In other words, a mathematical apparatus must adequately correspond to the phenomenon being reflected, since it itself in a specific sense is an abstract model of the described communications and relations. The requirement for basic information depends on the quality of the apparatus and its correspondence to the nature of object: the better the apparatus reflects practical communications the more economical it is. However, the reverse is also correct: the methods of investigation and the apparatus being used depend considerably on the completeness of information. Let us say that frequently scientists examine the process as random and apply the theory of probabilities simply because they still do not know its determining mechanism.

The break of social sciences was the stimulating motive for the development of new divisions of mathematics, thanks to which in the last decades the theory of the investigation of operations, the theory of games, the theory of the queueing, and linear and dynamic programming appeared, and also a number of new applications of the

traditional divisions of mathematics. Of special interest is the theory of games, worked out for the solution of conflicting situations in economics and an armed struggle. For the first time the concept of this theory was advanced by John Neuman in 1928, however its systematic account was published by him only in 1944 in the book "The Theory of Games and Economic Behavior," written in collaboration with a known economist and adviser to the American government on questions of defense Oscar Morgenstern. This theory was immediately evaluated by the scientific community as one of the most important achievements of science for the first half of our century. The theory of games received wide application in military investigations, and I. A. Poletayev was possibly right when he stated that "the theory of games is the mathematical basis of military art."[1]

In the theory of games it is postulated that the opponent is just as clever as we, and under this condition a search is made for the best line of behavior under the worst conditions, moreover a slip by the opponent leads to an increase in our prize. In its scheme this theory is applicable there where the interests of individuals or of groups of people collide. Such conflicts arise in any game, but on scales which are worthy of investigation. They are characteristic for the economic life of an antagonistic society and for war, which also is the creation of class antagonisms.

The theory of games does not investigate armed struggle itself, but a game which is equivalent to it in a specific respect, and the rules of which reflect the practical laws of war. Application of the theory of games begins when a matrix is composed in which all the strategies of the "reds" are depicted in the form of the digits arranged in vertical columns and the strategy of the "blues" — in horizontal lines.[2] The process of solving the game includes the

[1]I. A. Poletayev. Preface to the book by J. D. Williams "The Perfect Strategist or a Primer on the Theory of Strategic Games." Pub. House "Sovetskoye Radio," 1960.

[2]The word "strategy" in the theory of games is used somewhat differently from its use in military science. Here it designates a line of behavior or a selection; sometimes instead of the word "strategy" it is possible to encounter the word "alternative" in the literature.

finding of the optimum strategy which ensures the maximum gain at the most "clever" behavior of the opponent. The result indicates for which greatest gain it is possible to calculate in the worst situation. Solutions of this type are actually used in the planning of battle actions. For example, in the book by M. Metloff and E. Snell "Strategic Planning in the Coalition War of 1941-1942" the second part is called: "Planning, Taking into Account the Worst." Here it is said that in 1941 the organs of strategic planning of the USA originated from a calculation that hitlerite Germanium will gain a rapid victory on the European continent and organize an invasion of the USA.[1]

However, in this example it is possible to note a shortcoming of such a solution. Under the practical conditions of war an exclusive calculation for the worst can predetermine such an arrangement of forces and facilities, which will not allow one to take full advantage of an error, miscalculation, or failure of an opponent and in the end will lead to the unjustified expenditures of human and material resources. The calculation by the USA on the rapid victory of hitlerite Germany in Europe was the result of an incorrect representation of the power of the Soviet Union. Such basic positions of strategic planning were one of the reasons for the low effectiveness of actions of the US Army in the Second World War. Optimum strategy, giving a guaranteed minimum of gain in the case of the unerring play of an opponent, is not the best against each of the strategies accessible to it.

The theory of games is generally not very strong in the solution of problems similar to those described above. It is effective during the investigation of mass problems of a tactical scale, in the course of solution of which additional information does not enter or cannot be immediately calculated. Then they apply the optimum mixture of strategies, although against each of the concrete strategies of an

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[1]See M. Metloff and E. Snell. Strategic planning in the Coalition War of 1941-1942. Pub. House for foreign literature, 1955.

opponent it would be possible to apply more effective measures if we had the appropriate information.

The theory of games is internally connected with the theory of information, since uncertainty about intentions and actions of an opponent usually is an essential element of conflicting situations. It seems to us therefore that military cybernetics in the future will become a more integral science than now. The fact that with the presence of supplemental information ΔI about the strategy being applied by the opponent it is possible to achieve an increase in gain by Δw, suggests the possibility to consider the value of military information on the scale of a game matrix. Perhaps here a certain possibility will be discovered by the quantitative evaluation of the maneuverability of the troops, which will make it possible to approach the solution to the problem of the optimum organization of control of troops. It is obvious that these assumptions must be verified.

As J. Williams writes, the theory of games now "is a healthy small child who can be taken away by plague or who can grow and occupy an important position but today it can give very little."[1] This uncomplimentary opinion is based on the following circumstances. In the first place, the theory of games now gives practically acceptable methods of solution only for comparatively simple games. More correctly it gives a prescription even for the solution of complex games, but to solve them, according to a remark by Williams, is as simple as "counting by one up to a million": at every stage it is known what the following step must be, but the path is incredibly long. Even high-speed computers now and then cannot cope with the problem. Apparently one of the main problems of the contemporary theory of games is the working out of simplifying assumptions and approximate methods of solution. In the second place, in games which possess a practical significance the volume of information is extremely great, which in a specific way influences the complexity

[1] J. D. Williams. A perfect strategist, or a primer on the theory of strategic games. Publ.House "Sovetskoye Radio," 1960, page 25.

of the rules of play. Thirdly, in practical situations cases when the gain can be evaluated by any one variable are extremely rare, and in the contemporary theory of games such a requirement is compulsory. It begins to work when a practical situation is converted into an equivalent game, the prizes of which are evaluated on the same scale.

The latter observation is especially important. No matter how complex the finished matrix is, sooner or later mathematicians will find a method for its solution: already solutions have been found for some types of endless games, simplified methods have been developed for a number of complex cases, etc. But the main difficulty is covered in the search for a method of representation of practical battle situation which is rich in colors and shades in the form of a diagram, in which only one unique parameter remains significant: winning. For this one must be able to correctly formalize this situation, interpret the laws of armed struggle, and be able to make up a sufficiently accurate mathematical model of battle.

Whether the solution will be useful or turn out to be senseless depends on how correctly the dimension of the prize is selected. In the mentioned book by J. D. Williams such a problem is examined. Two American fliers in the near east – Joe and Bill – due to idleness decided to play a game: they place into the cylinder of a revolver one cartridge and make up the rules of play, by which Joe either adds into the initial bank two packs of cigarettes, or only one, but in this case he spins the cylinder, places the revolver to his temple, and squeezes the trigger. If he lives then he passes the revolver to Bill, who does the same thing. This problem is solved by all the rules of the theory of games, its solution is such: the most advantageous strategies of both players are those when each time they place the revolver to their temple! This absurd solution is obtained because the prize was evaluated in packs of cigarettes, and the cost of a human life was implied as equal to zero.[1]

[1]See J. D. Williams. A perfect strategist..., page 96.

The theory of games represents a millstone, which grinds that which is placed under it. As Williams notes, "the process of abstraction and simulation, with the help of which we crossed from the practical world to play matrices, can require the intimate knowledge of the essence of the problems being studied, more extensive knowledge in the field of mathematics, more than resourcefulness...."[1]

The value of the dimension of prizes lies beyond the theory of games. This is the scope of the theory of investigation of operations, where this procedure is called the determination of the criterion of effectiveness. As A. F. Gorokhov notes, the selection of the criterion of effectiveness is "the basis and beginning of the investigation of operations."[2] Generally speaking, the criterion of effectiveness in the theory of investigation of operations and the prize in the theory of games are not at all one and the same. The first has an autonomous value, since with its help it is possible to compare the effectiveness of combat technology and to resolve extreme problems without resorting to the methods of the theory of games. However, one cannot apply the theory of games without it, and in this case it determines the dimension of the prize.[3]

F. Morz and D. Kimbell give an example of the determination of the effectiveness of various defensive facilities of English cruisers based on the results of their utilization in the Second World War. They point out that if one were to approach the calculation of sunk and damaged cruisers superficially, without trying to grasp the essence of the matter, then it would seem that their weakest point was antiaircraft defense, since more than 50% of all damages were

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[1]Ibid, page 97.

[2]A. F. Gorokhov. Preface to the book of F. Morz and D. Kimbell "Methods of the Investigation of Operations," page 11.

[3]Some authors consider the method of appraising the combat effectiveness, based upon the determination of the criterion of effectiveness and the subsequent finding of the extremum of this criterion, and the method of mathematical simulation are in principle different methods. With abstract reasoning this is apparently so. But in this case they coincide: in order to build a model-matrix it is necessary to find the criterion of effectiveness.

received from aerial bombs. But the matter concerns not only the extent, but also the type of damages which put a cruiser out of action for a certain time. Therefore when in the capacity of the criterion of effectiveness the number of months which a cruiser is out of action was applied (sinking is equal to 36 cruiser-months - the time for building a new ship), then it turned out that the weakest point of cruisers was the armor protection of the underwater portion of the hull, as a result of which total losses of cruiser-months from torpedo hits were one and a half times greater than from aerial bombs.

Having determined the criterion, expressing the essential side of a process, it is possible to make direct conclusions for the improvement of the combat qualities of newly constructed ships. But it is also possible to resolve a problem of such a kind. The headquarters of the "red" fleet has information, that the "blues" have two (or three, five) types of cruisers, moreover they have a strong air defense, but weak armor for the underwater portion of the hulls, the others vice versa (the problem can be complicated, taken into account other features of ships). The effectiveness of their defensive facilities, calculated by cruiser-months, is known to the "reds" from the processing of reconnaissance information. The number of each type of cruiser in the given theatre of military actions, and, consequently, the probability of their utilization in the expected operation is also known. It is necessary to decide what the "reds" should send against the "blues": bombing aviation or torpedo boats, and if a combination of them, then in what proportion (all the forces cannot be thrown against the cruisers: the headquarters of the fleet has other assignments and must achieve maximum effect with the minimum investment of forces and means). This is the assignment of the theory of games.

Of course practical assignments are more complex. For example, in the course of the solution of the military-game described above situation the need can arise for a temporary change of the criterion of effectiveness. Frequently in combat it is necessary, at least temporarily, to put the greatest amount of combat units out of action. In this case a bomb strike is evidently preferable. Finally, a ship

carrying nuclear rockets sometimes has to be destroyed at any price. And although not every such situation can be really calculated, the skillful utilization of mathematics will help to analyze it even in these complex cases.

In conclusion to the question about the theory of games[1] it must be noted that this theory also has an important philosophical-ideological value. Actually the theory of games was created for the analysis of conflicting situations between people. However, it turned out to be suitable to induce a struggle between inanimate automatic units and even to solve the assignments of coping with radio interference. These and similar facts indicate that the theory of games describes a broader class of phenomena than was initially thought, and in all appearances is an attempt to reflect in a mathematical apparatus a structural system of relations which originate from the basic law of materialist dialectics — the law of unity and the struggle of oppositions.

In recent years, along with the theory of games, extensive distribution has been gained by methods of linear and dynamic programming, the theory of graphs and of its specific variant — the system of line planning and control (SPU or PERT), the theory of queueing, and a number of other theories and disciplines, specially created for an analysis of social processes, economics and armed struggle. The majority of the new divisions of mathematics named here, including the theory of games, are combined under the general name — finite mathematics.[2] From a methodological point of view this branch of mathematics is of interest in the respect that it is

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[1]The reader who wishes to study this theory should turn to the following books: J. MakKinsy. Introduction to the Theory of Games. Fizmatgiz, 1960; R. D. Lewis and H. Raifa. Games and Solutions. Pub. House of foreign literature, 1961; Ye. S. Venttsel'. The Elements of the Theory of Games. Fizmatgiz, 1961.

[2]See J. Kemeny, J. Snell, J. Thompson. Introduction to Finite Mathematics.

as if a return to pre-Newtonian mathematics on a qualitatively new base. It does not resort to the notion of infinite set because it finds it unacceptable for the adequate description of discrete process and systems, characteristic for the higher forms of movement of matter. If up to the middle of our century the predominant position in mathematics was occupied by the study of "smooth" functions of a continuously changing argument, extremely widespread in physics and technology, then now the situation is changed. Economics, phychology, medicine, and military affairs required "finite" mathematics,[1] which was able to be developed because it leaned on the rapid perfection of digital computers, which are the weapons of "mathematical expansion" in the area social sciences.[2]

An important event in the development of mathematics was the spreading of the concept that in addition to solutions in the form of mathematical formulas solutions exist in the form of algorithms. An algorithm is a procedure, partitioned into discrete elementary steps, which prescribes a completely single-valued path from varied conditions of an assignment to a result. An assignment is considered solved, if a noninfinite sequence of operations which leads to a goal is indicated. It is important to note that an algorithm does not solve a concrete single assignment, but a whole type or class of assignments. This is the method of solving a mass problem.[3] An

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[1]The name "finite" in no way means that it can solve assignments only of finite or limited complexity. The "infinite" complexity of social relations is not an impediment for the utilization of this apparatus. For the dialectics of infinite and very large, but finite see A. N. Kolmogorov. Automatic machines and life. Collection "What is possible and impossible in cybernetics," pages 19-23.

[2]N. Wiener writes the Claude Shannon became "one of the greatest scientists of our century" namely because of a tendency "toward assignments about equipment of type "yes" and "no," such as the usual switches, which he evidently preferred over questions about the continuously changing values of the type of force of current running on a conductor" (A — a mathematician, page 174).

[3]See B. A. Trakhtenbrot. Algorithms and machine solving of problems. Fizmatgiz, 1960, page 90.

example of an algorithm can be any mathematical formula, but not every algorithm can be represented by a formula. For example, the grammatical and syntactic analysis of sentences can be expressed, not by a formula, but by an algorithm, which is represented in the form of protocol recording, tables, a matrix, or a specific chart, called an algorithmic tree. The theory of algorithms extended the possibility of exact solutions not only for assignments having numerical solutions, but also for such problems, which it is accepted to call logical. Namely such are the many problems being solved by a commander and his staff in the process of controlling troops. It is important that the investigation of algorithms, with the help of which operational-tactical assignments are solved, opens the possibility of the automation of their solution. The program of a computer is a machine algorithm, i.e., an algorithm, expressed in the terms of the elementary operations of a machine and made up in the language of a machine.

During the discussion of the question of possibilities of mathematization of military science and the application of computers frequently references are made to the existence of algorithmically unsolvable problems. Really the problem of algorithmic unsolvability is one of the fundamental problems of contemporary mathematics. In the works of K. Gedel, A. Turing, N. S. Novikov, and others it has been proven that specific classes of problems exist, for which it is impossible to obtain a general algorithm of solution.[1] However, in

[1]For example, A. Cherch in 1936 proved that the problem of the recognition of duducibility was algorithmically unsolvable: an algorithm does not exist, with the help of which it would be possible to establish accurately if a deductive chain exists which leads from any formula *R* to formula *S*. In 1946-1947 E. Post and A. A. Markov constructed concrete examples of associative calculstions, for each of which the problem of equivalence of words is algorithmically unsolvable. Subsequently on the basis of this result A. A. Markov established the impossibility of recognition of algorithms for a broad class of features of associative calculations. In 1955 N. S. Novikov proved the algorithmic unsolvability of the problem of the identity of groups. For this work in 1957 he was awarded the Lenin prize. For more detail see B. A. Trakhtenbrot. Algorithms and the machine solution of problems, Sections 12, 13 and Conclusion.

reality this is not a restriction. In the first place, limitation refers to an equal degree both to social and to natural sciences, but the latter achieved a high degree of mathematization. In the second place, in the works of A. Turing it is pointed out that the impossibility of obtaining a common algorithm for a whole class of problems does not at all mean the impossibility of obtaining particular solutions for each of the problems included in this class.[1] The main thing here is that the works of K. Gudel, A. Turing, and N. Novikov are constructed on the current mathematical apparatus and give solutions for it. Meanwhile problems which are not solvable in one apparatus turn out to be solvable in a more powerful one. It is possible that humanity will create an improved mathematical and logical apparatus, in which these classes of problems will find their resolution.

The weakness of the present logic-mathematical apparatus is determined by many reasons. As is known, the theory of algorithms is created on the basis of mathematical logic, all the systems of which (with the exception of Boolean algebra) are constructed by the axiometric method. The very methods of construction of the systems of axioms — extraction, abstraction, directed selection of these axioms from practical bonds and relationships of the material world — have

[1]General solutions — in general are a luxury. They can be obtained rather rarely. For example, an algebraic equation of the type

$$a_0x^n+a_1x^{n-1}+a_2x^{n-2}+\ldots+a_n=0$$

does not have a general solution. Moreover, it has been proven that the roots of a general equation of a degree above the 4th cannot be expressed through letter coefficients with the help of a finite number of additions, subtractions, multiplications, divisions, raising to powers, and taking roots. There is no general solution even for equations with real coefficients. But for particular and special cases such solutions exist, and the methods of exact or approximate solution are developed well. General solutions have been obtained for equations of the 1st, 2nd, 3rd, and 4th degree, and artificial methods have been developed for the solution of certain specific [illegible] of equations with numerical coefficients, then for [illegible] possible to find either an exact or an approximate solution with any degree of accuracy.

been developed and founded unsatisfactorily. In essence, here everything is based on intuition and the method of "trial and error."

Furthermore, mathematical logic is built on the basis of Hilbert finitism, a theory which prohibits the use of the concept of actual infinity as an insufficiently logically based and limits the basic premises to the concept of potential infinity. On a specific, and namely — present-day stage of development of finite mathematics Hilbert finitism is a necessary and fruitful concept. However, the utilization of the concept of actual infinity in other divisions of mathematics, for example in differential calculation, still never led science to a contradiction with a practical reality. It is completely probable, that the solution of these and a number of other problems will move mathematics forward and will make it possible to create an adequate mathematical model of armed struggle, considering its actual many-sidedness.[1]

For progress in the area of mathematization of military science there is great significance in the development of computational mathematics and high-speed computers. Their development turns many abstract possibilities of military science into realy attainable. Sometimes it happens that the principle of solution of one or another sociological, military-economic, strategic, or operational-tactical problem is known, but the calculations, logical constructions are so bulky that they cannot be fulfilled in some reasonably planned time. Earlier this had the result that investigators were forced to be limited to rough approximate results or to a qualitative appraisal of the basic tendency. Now the boundary of what is really possible has become wider. Mathematical and electronic simulation now and then proves to be a productive method for the solution of problems even in the absence of a general theory. Sometimes empirical selection with the help of a computer solves a problem more rapidly than its logical basis.

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[1]For more detail about Hilbert finitism see N. S. Novikov. The elements of mathematical logic. Fizmatgiz, 1959, Introduction. For concepts of actual and potential infinity see the Philosophical Encyclopedia, Vol. 1.

Now it is difficult to say with reliability on which paths the greatest success will be achieved in the mathematization of military science, however, it is important to understand that this process is the objective tendency of its development, and the capabilities of mathematics are far from being exhausted: neither the nature of the objects of investigation nor the nature of mathematics prevents this.

The mathematical description of the regularities of an armed struggle is a complex matter. It is highly improbable that any general mathematical theory, suitable for this goal, will emerge immediately and wholly. Most likely it will grow, gradually accumulating new methods. Therefore it is necessary to display the maximum attention and on no account allow arrogant neglect of particular, simplified, and approximate solutions, which now and then may be far from practice and sometimes trivial. Along with development these approximate solutions will become practically useful, they will serve as construction scaffolding, from which the building of the general theory will rise.

The possibilities of mathematical description and the logical formalization of the regularities of an armed struggle prove to be very dialectic. At each given step of development of mathematics and the theory of military art far from every process can be formalized. This will not allow mathematics at any moment to become the unique method of military science. But at the same time no boundaries exist, further than which the mathematization of military science cannot go. Just as in nature in principle there are not incognizable "things in themselves," so also in principle nonformalizable bonds, relations, and features do not exist, but only those which still have not been formalized. According to the attestation of Paul Lafargue, K. Marx considered, that "science will reach perfection only when it manages to use mathematics."[1]

[1]Recollections about Marx and Engels. Gospolitizdat, 1956, page 66.

The area of possible logic-mathematical formalization of the applicability of cybernetic devices is continuously expanding. Because of the nature of a machine program as the formalized result of human thought this sphere will always be less than the sphere of human activity on that part, in which people still did not reveal the quantitative characteristics of phenomena and processes. But in this case the sphere of human activity is not constant, with every year it is expanded. The deeper the regularities of armed struggle are learned, the more unformal problems will be placed before a commander.

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We will cite the brief results of an examination of a problem of logio-mathematical description of the processes of an armed struggle.

The clearly expressed technical nature of revolutionary transformations in military affairs, and the need for optimization and automation of control of the troops and weapons made necessary the development and introduction of mathematical methods of investigation of the processes of an armed struggle. In this case the tendency for the mathematization of military science is organically merged with universal directivity for mathematization of contemporary science.

In evaluating the outlook of introduction of mathematical methods into the theory of military art, one ought to originate from the fact that in the entire complexity of processes of armed struggle in their nature there is nothing which would indicate the impossibility of their thorough and comprehensive quantitative investigation. In the future they may be described by a strict mathematical or logical apparatus with any degree of approximation to reality.

Contemporary mathematical and logical apparatus already possesses the capability to reflect rather fully the processes of an armed struggle. And although this apparatus is far from being omnipotent, the progress of mathematics and logic, especially those of their

branches which are developed under the direct influence of the interrogation of social sciences, makes it possible to draw the conclusion, that in the future the role of mathematical methods in military science will increase. Without pretending to be a unique method fo the theory military art, mathematics in time will become one of the important methods of military-scientific investigations and the practical solution of operational-tactical and other military problems.

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2. The Role of Cybernetics in the Development of Military-Technical Sciences and the Perfection of Armament[1]

The role of science in the development of a military affair is growing rapidly. In recent years military specialists, during the analysis of the relationship of the military power of governments, started to consider their scientific potential separately. Cybernetics enters into a number of sciences, on which the military-scientific potential of a country depends primarily. It is obvious that not one theory or scientific discipline can be developed without testing the influence of all the other sciences, production, and military affairs. However, remembering this, it is possible to conditionally isolate and examine in particular the influence of cybernetics on military-technical sciences, the theory and practice of development of new models of armament, and the solution of strategic and military-transport problems.

Cybernetics exerts its influence on other military-technical sciences and the practice of development of armament in two ways: in the first place, by pressure with its basic concepts on the methodological approach of engineers and designers to the comprehension and solution of assigned tasks; in the second place by the direct utilization of its concrete methods and means in the given investigation or project.

The influence of cybernetics on this or that military-technical science does not always begin with the utilization of the method of

[1]Section 2 of Chapter IV. Pages 212-223 of the original document were not translated.

"black box," an algorithmic language, or electronic models. It can happen that either the given branch of science itself still is not ready for the application of methods and means of cybernetics, or cybernetics does not have the necessary mathematical apparatus and appropriate electronic technology. Therefore initially a certain "ideological" influence appears, when forms, drawn upon from cybernetics and not cast into a concrete method, are crossed with the concepts of given science, are transported to its soil.

Several systems exist, the nature of interdependencences in which have still only been investigated qualitatively, and about their structures it is known only that these are systems of complex dynamism which encompass feedback. That is, these are cybernetic systems. In that case one cannot apply mathematical methods of analysis and synthesis to them immediately. Nevertheless on the basis of the most general concepts and results of cybernetics it is possible to substantiate probability hypotheses about the behavior of such systems under specific disturbances, and to reveal determining criteria, parameters, and scientifically well-grounded methods of investigation.

For example, it is still difficult to say how, on the contemporary level of development of economic and military science, it would be possible to mathematically analyze and construct an electronic model of the mutual influence of the scientific and industrial potentials of a country, their joint effect on the quantity and quality of combat technology, the role of the latter in the change of means and forms of armed struggle, the reverse infleunce of the changing conditions of war on tactical-technical requirements for weapons, and finally the effect of all these changes on the trend and tempo of development of industry and science. For the investigation of this system cybernetic can still only offer a pattern of a complex dynamic system, consisting of a large number of elements connected in principle "with each other," a system which at the same time is constantly developing and striving toward self-equilibration.

It seems in this case that cybernetics does not give much. However, if one considers that scientists accumulated a great deal of

experience in the analysis and synthesis of systems, although simpler but nevertheless in some things similar to the given one (such, for example, as Ashby's homeostat), then it becomes understandable, that cybernetic analogies can play a definite heuristic role in the prediction and planning of the behavior of systems which still have been studied only qualitatively. The experience of work with analogous systems prompts that changes in any of their elements without fail will reflect on the state of all the other elements. Moreover sharp jumps and disturbance, as a rule, cause prolonged, sometimes dangerous transitional processes, and an attempt to improve maximally any one of the parameters of a system can lead to the sharp worsening of the others. As we see, even without giving quantitative appraisals, a cybernetic approach can facilitate the introduction of scientific methods of control, forewarn of facts of subjectivism, volitional improvisations, and prompt solutions.

Cybernetics prompted the extremely promising concept of a systematic approach to the solution of military-technical and strategic problems. In past decades design offices created each model of armament as an isolated one, not connected with the others. With such an approach the problem of designers was reduced to the improvement of a given model without considering the fact that it would be entered into a system of armaments, into a combat complex. To a specific degree this approach was considered valid, since the systems of armaments which were applied in past wars were less integral, single, and dynamic than now. Therefore frequently the features of systems proved to be equal to the sum of the features of elements. As concerns organic single, nonconsolidated systems, characteristic for the contemporary level of development of armament, then the previous conviction no longer corresponds to the truth. Cybernetic investigations showed that an organically integral system, composed of elements, each of which is good by itself, will not necessarily be the best on the whole, since in such a system the features of elements are not added up arithmetically. It can raise and emphasize the advantages of this or that element, but can also obscure or reduce them. In other words, when the given type of combat technology

is considered as an element of the system of armament, then the meaning of the concept "best" is changed: a given type is connected with a specific system and depends on its features, structure, and purpose.

An interceptor-fighter, wonderfully "fitting" into one system of guidance, can be unsuitable for another. Thus with a radius of action of a system of 500 km there is no need to require that the tactical radius of fighter aircraft be equal to 3000 km. Indeed the increase in the radius is attained at a dear price – either at the expense of armament and speed, or of maneuverability and rate of climb. This means a nonusable excess of range is not simply useless, but is harmful: it lowers the effectiveness of the system on the whole. In the given example it is rather easy to avoid error, in more complex cases it is necessary that a systematic approach become a methodological principle.

A systematic approach is necessary not only during the determination of tactical-technical requirements for armament. A need for it also appears in the process of planning of programs of investigations, designing operations, and the production of armament. If some elements of a system of armament, because of the over-expenditure of forces and of means, are designed and made ahead of schedule, then this will not accelerate, as it may seem from the beginning, but it will impede the completion of the whole project.

The practical embodiment of the concept of a systematic approach to the development of battle complexes was the creation of the method of planning, which in the USSR received the name "System of Network Planning and Control" (SPU), and in the USA – "Program Evaluation and Review Technique" – PERT. This method replaces the usual ribbon charts by network charts which describe each of the processes not apart, but systematically, in comparison with others. The SPU makes it possible to evaluate what sequence of processes forms a so-called "critical path" and limits an overall reduction of periods.[1] As was

[1]See Basic positions on the development and utilization of the systems of network planning and control. Edited by V. M. Glushkov.

reported in the press, this method was used in the USA in the development of submarines with the "Polaris" missile. According to the appraisal of American specialists, because of the utilization of the PERT system it was possible in three years to solve a problem, which in the case of conventional control and planning would have required no less than five years.

In the USA large scientific-research organizations have been created which are engaged in the investigation of systems of an armament and the development of a program of investigations. The appropriate administrative apparatus was also formed — in 1966 in the Department of Defense (USA) the post of assistant secretary for the analysis of systems of armament was introduced. He supervises the scientific establishments which prepare the data for the adoption of solutions on the development of such systems.

As considered by specialists in the area of organization of scientific investigations by industry, the SPU method is the greatest achievement in this area in the last twenty years. In this case it is very important, that the network chart can be translated into an algorithmic language and introduced into a computer, which in this way becomes a unique "electronic headquarters" of investigation. Along with the realization of the plan data are put into the computer, it compares them with the initial chart and works out the correcting orders, each time in this case shortening the period of the critical path while preserving the assigned economy of the whole project.

The aforesaid about systematization also holds true for the strategic area. In the case of an equal volume of industrial production of two governments the greater strategic potential will be held by the one which has more effectively solved the problems of optimum relationship of prewar reserves and current production, cooperation

[FOOTNOTE CONT'D FROM PRECEDING PAGE].
Publishing House "Ekonomika," 1965; The system of network planning and control (the programmed introduction into PERT) Publ. House "Mir," 1965; V. S. Kazakovtsev. The instrument of control. Publ. House "Sovetskoye Radio," 1965; Robert V. Miller. PERT — a system of control. Translated from the English. Publ. House "Ekonomika," 1965.

and independence of enterprises, geographical placement, and duplicating. On this will depend the mobilization readiness and the vitality of industry — the capacity to endure the blows of an opponent without a noticeable reduction in output.

It cannot be said that before past wars no one thought about this. Each of the enumerated problems found a more or less satisfactory resolution in the strategic programs of the governments and the plans of the general staffs. However, in practice it frequently turned out that the joint action of plans either did not have an effect, or it proved to be much less than expected. After the Second World War it became clear that an attempt to solve each of the strategic problems as an isolated individual does not lead to the development of a balanced, stable, and effective strategic system.

Against this background the advantages of socialist economics, the law of development of which is regularity and proportionality, became especially apparent. In recent years the measures being conducted by the Party and the government, directed to the strengthening of the scientific bases of supervision of industry, the deep economic basis of planning, and the investigation of the objective laws of the development of socialist economics, in the very best manner embody the concepts of a systematic approach to planning and control of the national economy and have an important defense value.

It would be an error to consider that the specialists in military-technical sciences prior to the appearance of cybernetics remained in complete ignorance on the questions of control of systems for military aims. Here one ought to mention that the basic cybernetic positions, concepts, and conclusions, which possess a serious heuristic value, made it possible for military engineers to think on a greater scale and more systematically than this was possible earlier. The cybernetic approach to the solution of one or another problem came forward as a concrete interpretation of the dialectic materialistic method, which requires a consideration of each phenomenon in all the diversity of its connection with the surrounding world,

and a consideration of the nature of the system, its prehistory, and tendency of development.

* * *

Today military-aviation, military-artillery, and naval sciences, such as aerodynamics, ballistics, radio navigation, the theory of stability of a ship, and many others have sufficiently developed and logically perfected conceptual apparatus, a solid mathematical base, and also a high degree of general engineering and logic-mathematical preparation of scientific workers in order to rapidly convert from qualitative cybernetic analogies to the concrete utilization of means and methods of contemporary cybernetics, to the concrete utilization of the theories of automatic regulation, discrete automatic units, information, the investigations of operations, and also to the utilization of the radio-electronic means for the processing of information, automatic devices, and telemechanical devices.

It is difficult to point out any type of contemporary armament, where electronic engineering, automation and telemechanics are not applied. Even in the ground forces almost all types of weapons contain radio-electronic devices. Thus, contemporary tanks have not only automatic devices for the reloading of the weapon, but also automatic devices which preserve the position of the gun in space, which ensures the conduct of fire on the move. Tanks are provided with electronic devices for reconnaissance and fire control, and also navigation devices. It is simple to imagine a system which would make it possible to automatically transmit to the regimental CP information about the coordinates of moving objects, reserves of ammunition and fuel, and even about the condition of the crew. Moreover on the basis contemporary radio-electronics theoretically it is completely conceivable to develop a sufficiently effective armored remote-controlled vehicle.

In connection with the development of cybernetics the boundaries of the investigation of military-technical sciences have been enlarged

and previously void junctions filled up. In this respect the process of the development of such a discipline as the dynamics of flight is characteristic. If in textbooks, published in the past decade, the problem of control of an aircraft was limited only to the examination of the characteristics of the object of control, i.e., the aircraft itself, then in new training aids this question has found a considerably deeper and more comprehensive reflection, since now the system of control is considered as integral and closed, and including not only the object of control, but also the controlling system — the pilot. In this case the system "aircraft-pilot" is described by a single mathematical apparatus, creating the possibility for its analytical investigation and optimization.

The development of cybernetics, automation, and telemechanics led to the revision of many principles of the solution of engineering problems. One of such changes is described by Academician B. Petrov: "The mastering of space is characterized by the fact that here, unlike the entire preceding history of the activity of man" the first path "is broken not by man itself, but by automatic devices. They conduct the first reconnaissance, they investigate and "settle" outer space, and only then man takes his turn."[1]

This is a very interesting symptom, which entails new changes in views of the "interrelation" of man and machine. Still very recently in the literature dealing with the sociological problems of the development of technology there were indications of the steady rise in the number of emergencies, traumatism, and catastrophes in production and transportion, and the unconditional conclusion was made, that in proportion to the complication of technology the danger of working with it rises. In this case the gloomiest predictions in respect to the future of technical progress were frequently expressed. Of course the increase of the danger of technology in proportion to its development actually exists. However, it is opposed by another tendency, connected with the fact that the development of technology

[1] "Izvestia," 18 April 1968.

at the same time makes it possible to improve interlocking, to introduce duplication, and to increase the reliability of systems. Thus the realization of the automatic docking of spaceships in orbit can be considered not only as a step in the future mastering of space by man, but also in the plane of increasing the safety of space flights. In the case of the failure of devices which ensure the return of a spaceship to earth, for example the failure of braking engines, a rescue ship will be sent out which will converge with the troubled ship, dock with it, take its crew on board, and return to earth.

At each stage of development of technology and in any concrete case the resulting measure of danger is made up of the joint action of both the above named tendencies. In this case the danger increases sharply when engineers and investigators disregard the achievements of automation and telemechanics. As reported by R. Young in the book "Brighter Than a Thousand Suns," in atomic laboratories in the USA there were cases when the critical mass of a uranium bomb was determined by man, who by hand guided the pieces of nuclear fuel and held them at a distance from one another with the help of... a screwdriver. Some scientists received a lethal dose of irradiation in this case. But indeed at that time automation and telemechanics were developed to the extent that such a problem could have been basically solved without the direct presence of man.

If in the early stage the influence of cybernetics sometimes caused "a children's disease of overautomatization," then its more mature influence, on the contrary, is cured of this enthusiasm. For the contemporary state of military-technical sciences a characteristic is the fundamental understanding of the goals and assignments of automation, the criteria of its effectiveness, and the true relationship of man and technology in an armed struggle. On this basis a trend appears to make better use of the characteristics of man as a link in the system of control, to more completely reveal the specific advantages of an operator over present-day automatic devices. In this case some recommendations of human engineering and its

adjacent disciplines have an important value for the development of correct technical politics in the area of construction of combat technology.

Let us take for an example this problem: what is the maximally permissible complexity of operations, executed by soldiers in the process of an operation and the combat application of armament? It is obvious that this depends on a number of reasons: the level of literacy of the soldiers and officers, their training, etc. Among the enumerated factors an important place is occupied by the physical stress, induced by the degree of danger, to which a soldier is subjected during the realization of his duties. The greater the danger, the stronger the influence of nervous stress: it causes errors, short duration failures, and omissions. As a rule the level of danger in the period of preparation of technology for battle is noticeably lower than in battle itself. Therefore the permissible complexity of an operation can substantially exceed the complexity of operations in the process of combat application.

For nonautomated combat technology a characteristic is the very insignificant drop in complexities: this technology is simple in operation, but then in combat it is necessary to perform a mass of difficult operations. Thus, in antiaircraft artillery prior to the introduction of automation, before firing it was necessary to measure "by hand" the distance to the target, its course, altitude, speed, and direction and velocity of the wind; with the help of nomograms, tables, and a slide rule the firing data was processed, by voice the command was given, with the aid of handwheels the gun was laid on the assigned angles, etc. In this case one individual error reduced all the efforts to nothing. The automation of battle technology creates the possibility to expediently redistribute the complexity of its operation and combat application. As a rule the servicing, adjusting, and regulation of automated combat technology are rather complex. However, this substantially simplifies the operations being performed in combat.

Of course the problem of complexity of a weapon and combat technology is not only industrial-psychological. Its solution, as was already stated, is influenced by a mass of other factors. However, an approach from the point of view of the optimum matching of man and technology on the basis of the reasoned application of automatic devices is one of the components of the solution to this problem.

A number of means and methods of cybernetics have found application in those branches of military-technical sciences which are concerned with questions of the organization of operation and repair of combat technology. Judging from data in the press, in the engineer-aviation service and in the tank troops network charts for the repair, routine work, and the servicing of equipment are accepted. The practical application of methods of the theory of queueing guaranteed the well-timed withdrawal of equipment for repair, it liquidated lines and idle periods. Data processing of failures and reclamations with the help of a computer and the application of the theory of reliability created capability to rapidly and effectively increase the operational characteristics of armament.

Finally, the new approach to the problems of logic and the methodology of military-engineering investigation is bound by its appearance to the influence of cybernetics to some degree. The study of information processes and algorithms in technical devices aroused interest in the analysis of the regularities of the processing of information in the head of the scientist himself and the investigation of algorithms of engineering thinking. A stage was begun when the object of an investigation became the "technology" of scientific thought itself. The strict scientific analysis of this problem convinces us that the majority of the cognitive operations, carried out in the course of the solution of standard scientific and engineering problems, can be dismembered into elementary components, studied, and on this basis optimized.

It is characteristic that namely a cybernetic approach prompted the concept, by following which the specialists in dialectical,

formal, and mathematical logic, possibly, will find a variant for depicting the logic of science on the whole, and not its separate fragments, as this takes place now. In this respect the hypothesis of the French cybernetic specialist L. Couffignal is interesting. He proposed to build an original thinking model: to present science as a complex "machine," on which the scientist operates. In this case the logic of actions of an "operator" in a specific way will reflect the hidden qualities of the "machine."

In our view, the problem of the investigation of logic and the methodology of military-technical sciences is one of the important promising problems that requires the combined efforts of military philosophers, logic experts, psychologists, and engineers.

The means and the methods of cybernetics find application not only in the course of the solution of theoretical research problems, but also in the practical development of new models of armament - in the planning of design operations, in the basis of tactical-technical requirements, the calculations, designing, and testing of the prototypes of weapons and combat equipment.

Until recently the basic method of planning was the so-called staged planning on the basis of conventional (ribbon) charts. Such planning is unconditionally necessary, since it gives a clear outlook of the work for a year, three years, or the entire period of investigations. But together with this, in staged planning, if it is not supplemented with continuous planning, there are also shortcomings. They include the fact tnat the updating of the plan based on results achieved is done only on the conclusion of the stage. With the introduction of the methods of network planning and electronic computer technology the capability appeared, along with staged planning and problems originating from it, to conduct continuous optimum planning, which permits the timely and effective use of one or another technical plan. The contemporary methods of the planning of investigations and developments make it possible considerably earlier than before to note a disproportion in the course of work of

various departments of NII [scientific research institute] or KB [design office] and in proper time to develop the correcting orders for the redistribution of forces and means.

An important stage in the development of a weapon and combat technology is the determination of tactical-technical requirements. For developing them it is necessary to consider the capabilities of contemporary science and technology, and also the "demand" for troops in new systems of armament.

In order to formulate a technical task for the projecting of a new model of a weapon it is necessary to conduct complex laborious investigations, which include the evaluation of the reliability, vulnerability, and combat effectiveness of existing armament, to expose its shortcomings, and to evaluate capabilities allowing for the probable opposition of the enemy. Up until the introduction of mathematical methods of investigation and the application of computers the statistical material collected in many instances was not processed sufficiently, as a result of which the deductions and conclusions were sometimes made on a comparison of a small number of models and on the results of separate tests, which did not exclude errors and were not free from improvised solutions.

Inasmuch as combat technology is developed with a calculation on the future, then most frequently the conditions under which it will be applied – the combat complex, where it will be introduced, and also the armament of the enemy which is counteracting this technology – actually does not exist yet. Therefore in the course of development of tactical-technical requirements the necessity is appeared for a mathematical or electronic model of the future conditions of application of the given model of armament.

No less a role can also be played by the methods and the means of cybernetics in the very process of the projecting armament. First of all the automation of computational works creates the possibility for a reduction in the number of evaluation calculations. It is

widely known, that engineers, although in many instances they know the mathematically exact dependences, in practice are forced to use evaluation, frequently empirically selected relationships. Thus radio engineers during the calculation of electronic equipment and antenna devices use formulas which give a deviation from true value by 20-40%. This is done because exact formulas are too bulky and now and then it is simpler "to pull" a tested sample by trial and error of parameters and fine adjustment than to stick to endless calculations. The value of computers in this case consists of reducing to the minimum the evaluation calculations and the calculation of magnitudes of possible errors.

At the same time the automation of design works makes it possible in many cases to pass on to optimum projecting. In design practice prior to the introduction of the computer the possibility of selection of an optimum variant most frequently existed only as an abstract possibility. The labor input of calculations usually forced a limitation of comparison to two or three and a maximum of five variants. The better of them was selected. But there was never any assurance that the best of all possible ones was among these five. With the introduction of the computer the abstract possibility increasingly more frequently turns into practical, since the development of a large number of variants of calculation and their comparison based on assigned criteria becomes a completely practical matter.

The effect, achieved with the help of means and methods of cybernetics, of the acceleration of scientific investigations and design works is extremely important. Based on foreign data, the period of development of a contemporary aircraft or rocket comprises from 4 to 10 years. This even for peacetime is too long a period. And meanwhile it is possible to foresee that in the course of war the need will arise for the development of new forms of weapons and the adoption of urgent countermeasures against the new combat technique of an opponent. The wide utilization of network planning and electronic computer technology with the previously worked-out programs for projecting standard blocks and assemblies will make it possible, directly in the course of war, to rapidly develop projects, to obtain

and multiply technical documentation, and to start new combat equipment into production.

Computer technology made it possible to approach the planning of armament of a complexity which was inaccessible earlier. Today the development of rockets, aircraft, and the computers themselves is unthinkable without the utilization of computers. A specific role in the process of development and testing of new models of a weapon and combat technology belongs to a mathematical and electronic simulation. Electronic models make it possible to learn very much about a future flying apparatus even before it is formed into metal at plant stocks. On an electronic model it is possible, for example, to test how a future sea vessel will handle in a storm. In this case to control an electronic "storm" is rather simple: it is possible to change amplitude, periodicity, and the direction of a wave, to imitate wind gusts, etc.

As we see, the means and methods of cybernetics have already found wide application in the practice of projecting and in the development of weapons and combat technology. An analysis of the tendencies of the development of military-technical sciences shows that in the future these methods and means will acquire even greater value.

* * *

We will give a brief summary of what was said in this division.

Cybernetics is one of those sciences, on the development of which the military-scientific potential of a country depends to a considerable degree. It is of invaluable help to the theory and practice of development of the models of armament and to the solution of strategic problems. Cybernetics manifests its influence on other military-technical sciences most frequently by means of the [illegible] of its concepts on the trend and the order of thought of scientists or by means of the direct application of its means and methods in investigation or designing.

The concepts of cybernetics are fruitful even in those cases when the systems have been investigated only qualitatively and there is still no possibility to pass directly to the application of mathematical models and the utilization of electronic computer technology. The concepts of cybernetics can play an important heuristic role, prompt hypotheses, and sometimes to forewarn of volitional improvisations, and facilitate the introduction of a scientific approach to control and directing of the development of armament.

The application of methods and means of cybernetics makes it possible to correctly determine technical politics in the area of the automation of weapons and combat technology, to set forth the basic tactical-technical requirements, to substantially shorten the periods of investigations and development, and in a number of cases to pass to the optimum projecting and improvement of "technology" of engineering thought.

3. The Methodological Questions of the Application of Cybernetics in the Training of Troops

In connection with the revolution in military affairs in the training of troops and in the work of military-training institution contradiction has arisen between the ever increasing volume of knowledge and the periods of service and training. The problem of increasing the effectiveness of education and training of soldiers received serious attention, since on its solution the increase in the combat power and combat readiness of the Soviet Army and Navy, the rational utilization of the means set aside by the state for the defense of the country, and also the expedient utilization of human resources depend in many respects. In recent years for the solution to this problem more attention is being gained by methods of programmed training, cybernetic teaching machines, and network charts for the planning and organization of the training process. More frequently in the course of military-educational investigations the cybernetic method is applied.

Work on programmed training and utilization of learning machines was begun in our country in the year of 1962 on the initiative of the Scientific Council on Cybernetics of the USSR Academy of Sciences. Somewhat later, in 1964, an Interdepartmental Council on Programmed Training was created. It is characteristic that unlike foreign investigations, where work on programmed training flowed exclusively in the channel of pedagogic and of psychological investigations, in our country attempts were made at the cybernetic interpretation of the concepts of programmed training, which in conjunction with the deep psychological-pedagogic analysis of the problem produced definite positive results.[1]

A cybernetic approach to the problems of education and training begins with the construction of a model of this process. It is not

[1]See Problematic notes on the work of the Scientific Council on the complex problem of "Cybernetics" of the Academy of Sciences, USSR for 1959-1967 ("Information materials of the Council," 1967, No. 11), pages 179-183.

compulsory that this model be materialized, let us say, in an electronic circuit, but it can exist only in the capacity of a logic-mathematical description of a process. It reflects the approach to training as a process of control of the shaping and development of the psychic features of the person being instructed. A simplified variant of this model is shown in Fig. 4.1. Here the instructor and trainees represent the links in the system of control, and the process of education and training — the cycle of transmission, processing, and storing of semantic and emotional information.

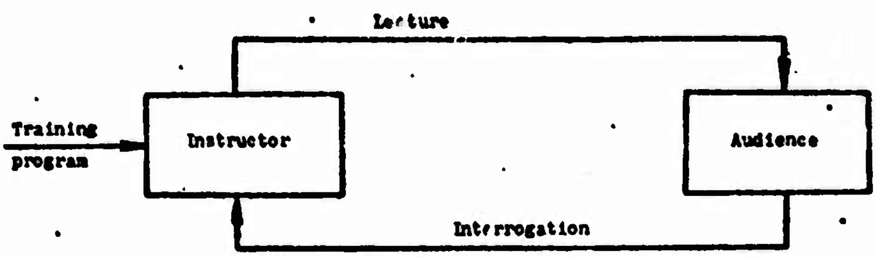

Fig. 4.1.

Such an approach will not replace all the remaining methods of investigation of education and training process. It is limited from the social, psychological, and pedagogic points of view and is an abstract, generalized construction, in which for the sake of clarification of the most significant bonds everything special and specific, peculiar to each concrete association, is dropped.

The cybernetic model of a process is not a symbol or hieroglyph, but a sufficiently accurate, in the required relation, copy of a practical process which makes it possible to use the general laws of control revealed by cybernetics for the finding of the paths of increasing the effectiveness of education and training.

Let us examine some consequences which stem from the analysis of such a model. The capacity of any controlling device to guide a process is determined by its capability to process and transmit the controlling information. Since the source of information in our

system is the thinking apparatus of the instructor, and inasmuch as language is the "direct reality of thought," then with a certain error (connected with a disregard of emotional information) it can be considered that in the absence of such auxiliary means, as the class board, posters, and so on, the carrying capacity of vocal apparatus of the instructor and its rational utilization determine the effectiveness of regulation in the given system.

For any existing human language a specific surplus of information is inherent which ensures the interference-free convenience of pronunciation. However, the surplus is considerable, and besides unjustified, it grows because of the poorness of lexical reserve and the imperfection of grammatical and syntatic forms. It has been established also that in the mastering of informations a large role is played by vocal emotional information, contained in semantic stresses, timbre coloration, the peculiarities of modulation of the voice of the instructor, etc.

In all apparentness, with equal scientific qualification of instructors, namely minimum redundancy, a necessary condition of which is the logical order of presentation, and also the emotional saturation speeches, mainly distinguish the language of a good instructor. Hence it follows that in the interests of the optimization of the process of education and training it is important to investigate comprehensively the logical structure of information and to find the special methods of teaching the art of speech in the system of training military-pedagogic cadres, commanders, and political workers for the troops.

The quality of control in any system of education depends also on the carrying capacity of the channel of communication, with the help of which the controlling device is connected with the object of control. The most capacious channel of communication [illegible] the external world is the visual channel. Its capacity is several dozen times greater than the capacity of the auditory channel. Therefore already several centuries ago the language of science and

technology was the drawing, in which "the transmitting side" accumulates information ahead of time in order to transfer it along the most capacious channel belonging to the "receiving side." In this case the drawing plays the part of a certain transformer, the matcher of the information characteristics of the transmitter and the receiver, making it possible to substantially shorten the time for the transmission of information.[1]

In this way, a cybernetic model of the education-training process opens a reserve for increasing its effectiveness — the possibility of the matching of the information characteristics of the instructor and the audience because of the maximum utilization of the visual channel of the latter (see information matcher "A" in Fig. 4.2). The practical realization of such an information matcher now are the class board, schematics, posters, models, lantern-slides, and motion-pictures. Their wide general utilization can and should play a substantial role in increasing the effectiveness of training. However, the absence of a scientifically proved procedure for the utilization of these means sometimes paralyses the expected effect. For example, the investigation of the effectiveness of various means for the utilization of motion-pictures in the training process, conducted under the supervision of Professor A. A. Lyapunov, showed that an incorrect procedure can lead to a sharp (sometimes by more than 10 times in respect to the best result) lowering of the percentage of correctly fulfilled control works on the theme being studied. In this way, along with the search for new effective means of matching the information characteristics of the channel of communication "instructor-audience," such as the programmed training and teaching machines, it is necessary to investigate thoroughly the procedure of application of the generally accepted means, the reserves of which are far from being exhausted.

[1]The theoretical basis of such a transformation of an information is the position of the theory of information concerning the possibility of change in the configuration of information under the condition of preserving its volume: $F_1T_1A_1 = F_2T_2A_2$, where A_1 and A_2 — the coefficients of the relationship of signal and noise, T_1 and T_2 — the time of transmission of information, F_1 and F_2 — the width of the band of frequencies (see Chapter II, Section 2).

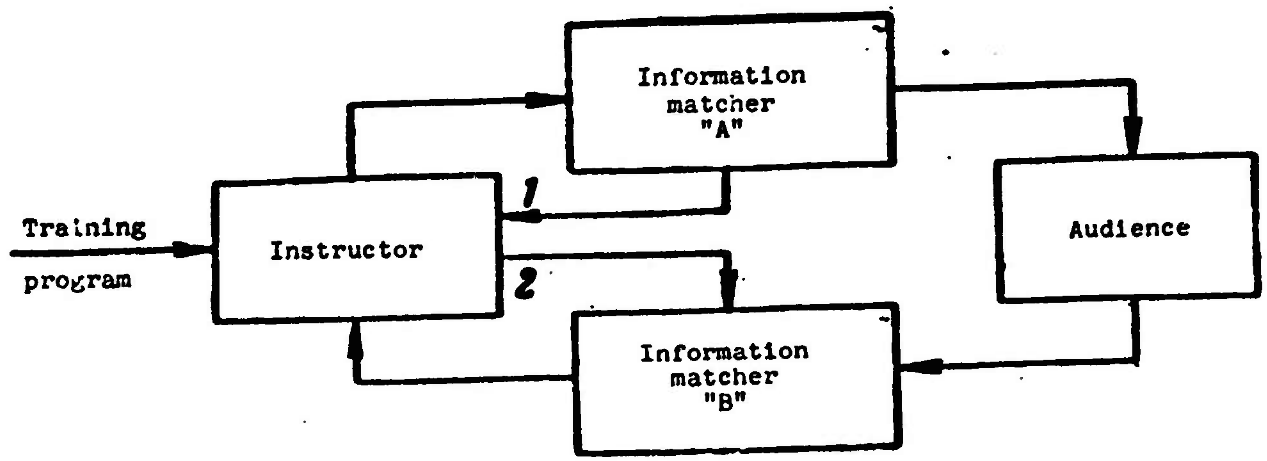
Training
program
Instructor
Information
matcher
"A"
Information
matcher
"B"
Audience
1
2

Fig. 4.2.

A necessary condition for the functioning of any system of control is the presence of a channel of reverse communication. The effectiveness of control depends both on the quantity of information transmitted over this channel, and on the extent of delay with which the information arrives at the controlling device. At a specific extent of delay the system not only ceases to regulate the process, but just the opposite, it swings and destabilizes the object of control.

All this is completely correct in the system "instructor-audience." For example, linguists consider that for complete control over the process of teaching a foreign language an exchange of information between the audience and the instructor should take place on the average not less than every 8 seconds (150 confirmations in 20 minutes of lesson). Under these conditions a reverse communication exists practically continuously and information about the mastering of new material by the listner is received without any delay. Many instructor-mathematicians consider that during a short period of time (2 hours) and at the price of great volitional stress it is possible to effectively control the actions of each listener and react to each of his errors in a group consisting of 15 persons. However, as a rule, with the usual sizes of a training group the circuit of reverse communication is chronically overloaded. If it is still considered that the channel of communication "instructor-audience" is simplex, i.e., operates either on reception or transmission, it becomes clear that with the contemporary "technology" of the training process reverse communication can be connected to each of the trainees for a short, incommensurable with the general period of the training process, period of time and is expressed only in such forms of control as incidental interrogation, a check of summaries, control and course of work, seminars, and examinations. Being deprived of the possibility of controlling the process of thought of the listener, an instructor is forced to be satisfied only with checking his results, while the goal of training consists mainly of the shaping of the process of a thought.

With an overload of reverse communication and incidental control cases are not excluded in which the signal about trouble with the

affair on the part of some trainee enters only when the initial insufficient incomprehension of the material already led to complete inability to master the course further. Here the reason for the passiveness of the listener is hidden.

An increase in the effectiveness of reverse communication can be achieved by the introduction into our system of one additional information matcher (see information matcher "B" in Fig. 4.2). The possibility of matching the information characteristics of this circuit is based on the fact that inasmuch as in the given system the source of informations is the instructor, then the answers of the listeners by necessity will contain a considerable portion of information, which for the instructor is surplus, knowingly known, and can be taken into account ahead of time in the appropriate way by an adjusted matching device.

In Fig. 4.2 we see apart from the initial closed circuit of control two supplemental circuits (1 and 2). Their presence already creates a certain possibility to improve the distribution of the flows of information in the given system. However, up to this moment we considered all listeners as a single object of control. In a certain meaning this is correct, since the association in which the education and training takes place represents a specific unity. Furthermore, with present-day methods of training it is necessary in the supplying of material and organization of control of assimilation to be oriented to some "averaged" listener.

For operational and individual control of the work of the audience it is necessary that each of them have the optimum possibility to match his information characteristics with the channels of direct and reverse communication of the system "instructor-audience." In the process of solving this assignment the need appears for the formation of supplemental "microcircuits" of control, [illegible] possible for each listener to regulate the rate of supply of material, in the case of necessity to receive the necessary explanations, and to control the correctness of assimilation. Now the diagram of the process acquires the form shown in Fig. 4.3. Here each listener has

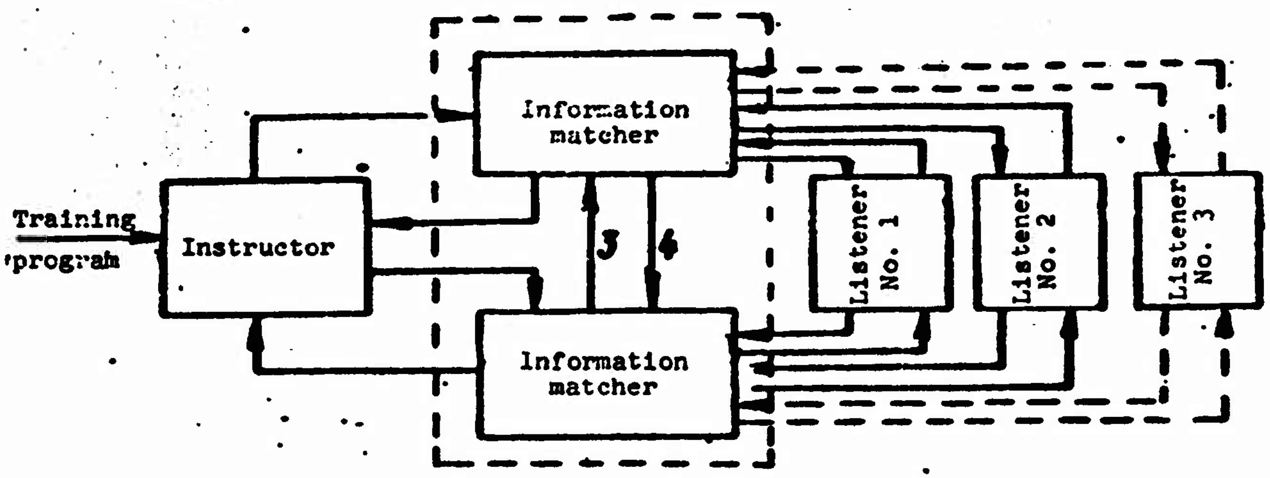
Training
program
Instructor
Information
matcher
Information
matcher
3
4
Listener
No. 1
Listener
No. 2
Listener
No. 3

Fig. 4.3.

an individual two-way communication with information matchers which are general for all listeners. In principle the assignment has another variant of solution: each listener can be provided with individual information matchers (Fig. 4.4). Having supplemented the arrangement in Fig. 4.3 with bonds 3 and 4, which coordinate the work of information matchers between one another, and the arrangement in Fig. 4.4 with bonds 5 and 6 for the same purpose, we arrive at the general schematic diagram of the training process with the application of programmed training material and the so-called teaching machines. The diagram given in Fig. 4.3 takes place during the application of the universal electronic information-logic machine, servicing the whole group of trainees; the diagram in Fig. 4.4 is valid for the case of utilization of individual teaching machines and programmed training materials.[1]

The cybernetic model presented in these figures gives a clear representation about the true place of teaching machines and programmed material in the training process (in Fig. 4.3 and Fig. 4.4 they are included in the broken rectangles). These devices and material by their nature are not able to abolish either creative pedagogic work or the duty of the instructor to educate the students. They also do not eliminate the need for persistent study and deep comprehension of training material by the students.

The true role of programmed materials and teaching machines consists of the optimum matching of the information characteristics of the instructor with the entire lecture-hall on the whole and with each listener individually and thus increasing the productivity of the training process.

[1]It must be noted that the difference between the last two schemes are more constructional than fundamental. For the student, if he has equal possibilities to match his information characteristics with the inputs and outputs of machines, the arrangements in Figs. 4.3 and 4.4 are practically identical.

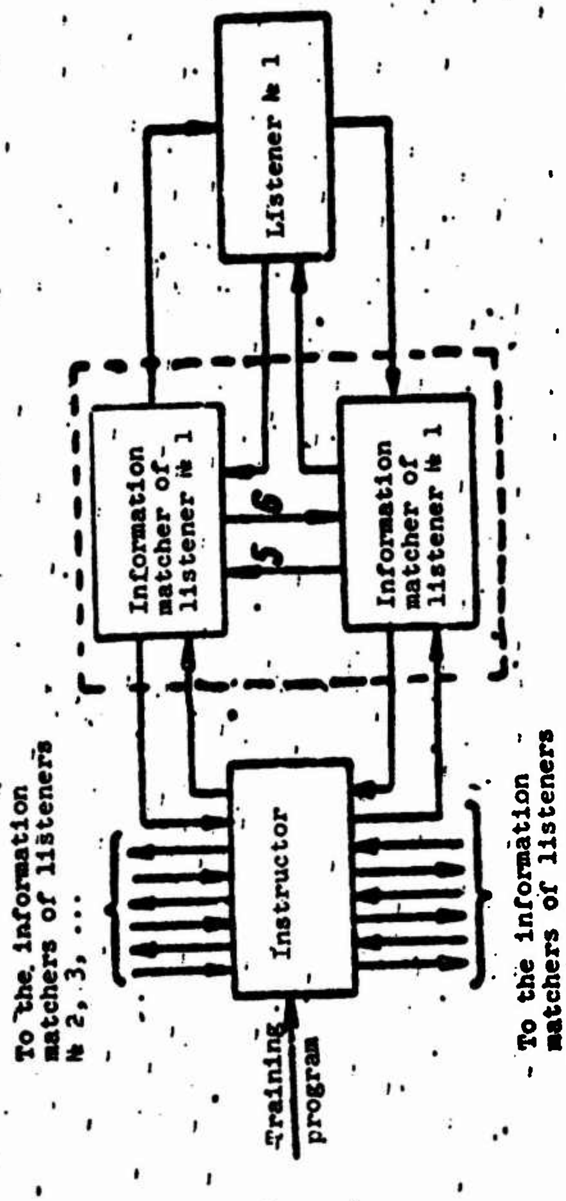
Listener № 1
Information matcher of listener № 1
Information matcher of listener № 1
Instructor
Training program
To the information matchers of listeners № 2, 3, ...
To the information matchers of listeners № 2, 3, ...

Fig. 4.4.

* * *

One of the methods for increasing the effectiveness of the training process and the means of realization of recommendations obtained during the investigation of the cybernetic model of training is programmed training. The most important features of programmed training are the following:

- the breaking up of training material into specific doses;

- the presence of effective control of the mastering of material of the program;

- individualization of training;

- optimum control of the process of assimilation of training material.

Practically the method of programmed training will be realized thusly: the trainee is issued training aids, compiled taking into account the work on a specific program, in which all the material of the following theme is located in a strictly logical order. This requirement is reduced to the need to investigate the optimum algorithm of the given course - the best sequence of presentation of material. In the case of nonfulfillment of this requirement subsequent work is useless.

Further the theme is decomposed into "quanta," or doses, each of which contains a certain logically completed share of material which contains new knowledge for the listener. The dimensions of a "quantum" are determined both by the complexity and logical structure of the material itself, and by the preparedness of the students. Materials for the training of young soldiers can be broken down into minimum segments (remember, logically completed), for the listeners at higher military training institutions they can be rather large paragraphs. After studying the following "quantum" of information

the student is given a question or assignment which can be solved only with the complete mastering of the given material.

Check the correctness of an answer to a control question (the solution to an assignment) in various systems of programmed training is carried out differently. A variant is possible when the listener is given from three to five answers, one of which is correct, and the remaining incorrect, but not obviously absurd, but plausible. Such a system is called a system of selective answers. For each of the answers a page is given, to which the student should turn if he is confident of his answer. A correctly solved assignment will allow the student to obtain the following "quantum" of information. With an incorrect answer the student is referred to that page, where the reason for his error is explained and an assignment, analogous to the first, is given. In other systems for checking the correctness of an answer the student is issued control cards, in which he enters his answer, and then collates it with the correct answer, given on the reverse of the page, or controls himself with the help of specific patterns. It must be noted that the selection of a form of posing it corresponding to the content of the given question is an exceptionally complex and laborious assignment, moreover the general rules for its solution have still not been developed. For example, some instructors note that sometimes the system of selective answers proves to be ineffective.

A logical diagram of one of the variants of programmed material is given in Fig. 4.5. The advantages of programmed training consist mainly of maintaining the constant activity of the listener. This is noted by all the Soviet and foreign teachers who were applying or investigating this method. Along with the mastering of knowledge the student forms habits of intensive independent mental work. A strict logical finish to a course allows the imparting of complex material to those categories of students who earlier were considered unprepared for this. With application of the described method the theory of the question is not separated in the consciousness of the student from the practical solution of assignments, as this often happens in the case of separation of a course into a lecture part

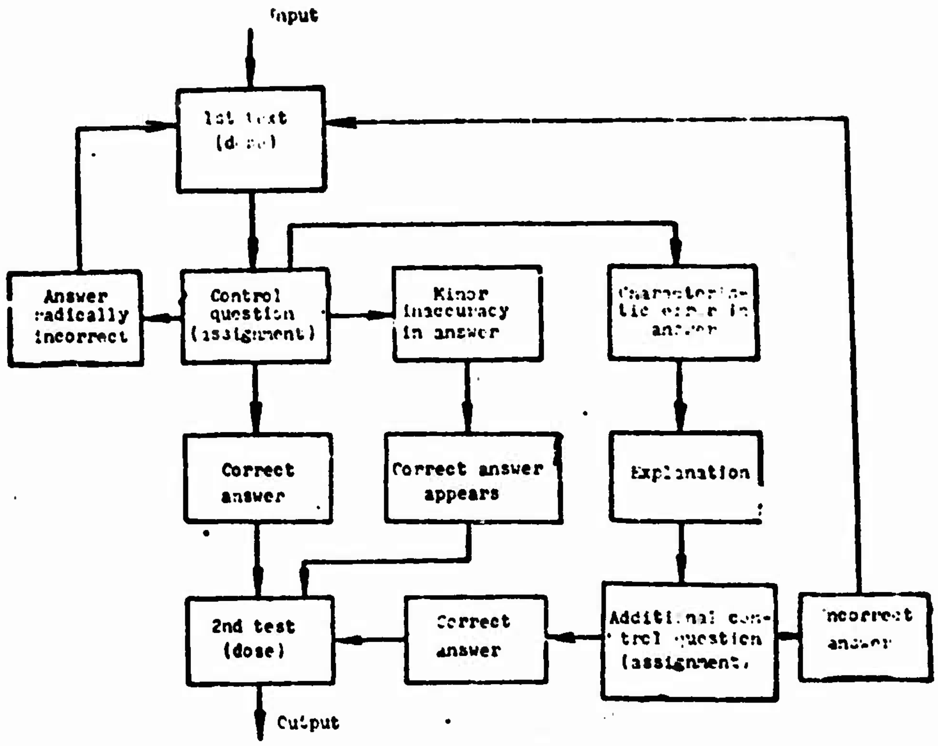

Fig. 4.5.

and practice, but is organically merged. As a result the students solve practical assignments considerably better than before.

With this method the exposure of incomprehension of some question by the listener is not set aside for control work or examination, but revealed and eliminated immediately. As is known, the significance of information depends on the prehistory of the system, i.e., on how much and what information is received and processed by the system up to the moment of receiving a communication. In this case because of the assimilation of all the previous material by the listeners the significance of each new information can be made [illegible]

A positive quality of programmed training is also the fact that a listener, having encountered difficulty in the understanding of a question, is not hurried by the averaged rate of supply of material,

but has the possibility to creatively comprehend it. The ablest students are able to cover the required program more rapidly and to have free time for deep research on supplemental material and participation in scientific research work.

In the Soviet Union and abroad considerable experience has been accumulated in the practical application of methods of programmed education in professional-technical, secondary, and higher training institutions, for several specialized courses have been developed, textbooks printed, and scientific investigations conducted. Thus, in the laboratory of programmed education at the Institute of Psychology of the Academy of Pedagogic Sciences, USSR a search for the utilization of algorithms in education is being carried out.[1] At the Institute of Psychology AN UkSSR in concord with the Institute of Cybernetics AN UkSSR an experimental analysis has been made of the dependence of effectiveness of programmed education on the arrangement of programs (linear, branched, adaptive) and the sizes of the dose of material.

As was reported in the press, positive experience in the utilization of programmed education have also been accumulated in a number of military training institutions of the Soviet Army and Navy. The information obtained helps in the effective teaching of a number of physical and mathematical disciplines, military-technical sciences, the material part of weapons, and battle technology. However, at the contemporary level of development of methodology, theory and the practical procedure of programmed education its application to the study of disciplines of social-economic and operational-tactical cycles (with the exception of some divisions) is still premature, although there is no doubt that in the future programmed education will occupy a considerably more important place than today.

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[1]The basic results of these investigations have been presented in the monograph by L. N. Landa "Algorithmization in education." Publishing house "Prosveshcheniye," 1966.

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A logical addition to the methods of programmed training is the utilization of so-called teaching machines - electromechanical devices, electronic computers, and trainers. The programs placed in them ensure the control of the training process, carry out operational control of the actions of the trainees and in proper time correct the errors made by them in the assimilation of material, and they also change the order of supply of semantic (logical) information depending on the nature of these errors.

This means of mass communication, such as the cinema, tape units, television, and various kinds of stage presentations, were applied in education even before the appearance of the methods of programmed education and now they are often used outside of any connection with it. The teaching machine - this is the next and a very considerable step in the development of methods of application of technical means in the training process and in the development of programmed education.

Not every teaching machine will realize all the functions enumerated above, in complete volume this will be done only by the most perfect instructing complexes on the basis of computers. The practical needs of the training process and economic considerations dictate the utilization of simpler devices. Rather effective among these are the so-called *machine-controllers*. Their constructional realization can be very diverse depending on assignment. It is possible, for example, to have such a variant. Placed in the casette of the machine is a certain quantity of cardboard cards, each of which is divided into two parts (Fig. 4.6). On the right half of the card the assignment is recorded, and on the left half with the help of punched openings the answer to it is coded. With the depressing of the start button [illegible] following [illegible] is suppl[illegible]
place," where it is situated so that the right part is visible to the trainee and the left is superimposed on a contact panel and forms a "template," with which the trainee's answer will be compared when

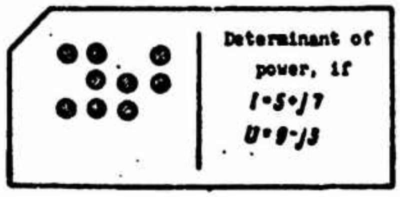

Fig. 4.6.

he introduces his solution into the machine with the help of a set of switches or buttons on the front panel. The check of the knowledge of the student can consist, for example, of five assignments proposed in series. Upon termination of the check a rating of the knowledge of the student appears on a light tableau in a five-point system.

In many higher military training institutions for checking the readiness of the audience for carrying out of laboratory works machine-controllers are used. The instructor previously with the help of switches inputs into the machine the codes of the correct answers and the number of points calculated for each of the answers (for example, for the first – 2 points, for the remaining – one each). The student places the switches in the positions which correspond to the codes of answers. After setting of the last switch the machine gives out a rating. As shown by the experience of application of such machines at the Air Force Engineering Academy [VVIA] imeni N. Ye. Zhukovskiy and the Kiyev Higher Engineering Radio-Technical Air Defense School [PVO], the quality of control of the training of the audiences for laboratory work in this case proves to be sufficiently high, and the time for checking their knowledge comprises no more than 5-10 minutes. If one considers that usually for this procedure from forty minutes to an hour is set aside, and the audiences in the time taken for education at a higher educational institution can perform hundreds of laboratory works, then the economy of time proves to be very noticeable.

More complex machines are possible which are capable within certain limits of analyzing and evaluating an answer, and reporting to the student about errors committed by him. It is obvious that the

most complex and laborious part of the work is the composition of questions, the selection of assignments, the selection of a logical system, and the designing of devices which meet the requirements of the training institution and the specific nature of the subject. Such machine-controllers can be effective in the taking of tests on the material part of weapons and battle equipment, during a check of skill in operation of equipment and the skill to eliminate malfunctions and during examinations on many military, military-technical, and general theoretical disciplines. Machine-controllers will also find application in the checking of course and control works with a mathematical bias. Thus, instructors G. N. Alekseyev and G. G. Maul' proposed a method of checking control works of extension students in the course "General thermal engineering" with the utilization of the "Ural-1" computer. With a considerably higher quality of control the time for checking is shortened by approximately 10 times, and the money savings for the All-Union Correspondence Polytechnical Institute can be evaluated at 135-270 thousand rubles per annum.

Another variety of teaching machines are the *machine-consultants*. They, as a rule, have a table of questions, on which they can give information to the student. Having found in the table a question which interests him, the student inputs its number or code into the machine. The necessary information is stored in the machine on magnetic tape, lantern-slides, and film, and with the help of a tape unit or projector with programmed control it is given to the student.

The effectiveness of machine-consultants is determined by the capacity of their storage and by the means of controlling them. If the volume of information located in such a machine can be concentrated in one reference book with a subject index, then preference should be given to a reference book or a card index as a cheaper and portable means. Only in the case of a large volume of information, when the usual methods of finding the necessary section are too bulky, or if the information changes very rapidly (in a time measured by days, hours, or minutes) the utilization of data processing machines is expedient. Most likely the area of effective utilization of such machines is scientific-research work and control of combat actions of troops, but not the training process.

Unification of the machine-consultant and the machine-controller into a single system of control creates a new device, which can be called a *machine-coach*. It not only advises the student, but allows him to verify the level of his understanding of the material.

Machine-consultants, controllers, and coaches are applied in the auxiliary operations of the process of training. However, teaching machines can be used even in the main cycle of the training process — to supply new material to the students. Namely such machines are accepted to be called *teaching*, they are the complex of all the previously enumerated devices. The logical diagram of this complex is analogous to the structure of programmed training and is distinguished from it by the fact that all the auxiliary operations, on which the student in the case of nonmachine training spends unproductive training time by being distracted and scattering his attention, are mechanized. For example, after the correct solution of an assignment the student here should not find the necessary page in a pamphlet; the correct answer is a command to the machine to show the following text or a diagram, to turn on the appropriate segment of magnetic recording in order to give the necessary explanations. One of the variants of a logical diagram of such a machine is given in Fig. 4.7. Here rectangles show the operations performed by the machine, and the circles — the organs of control which are used by the student. The dotted line designates the console of the instructor

As it is easy to notice, in this variant training is organized according to the diagram in Fig. 4.4. In the case of the utilization of an electronic information logic machine, servicing all the students simultaneously, the training will be organized according to the diagram in Fig. 4.3.

Among the problems connected with the advent of teaching machine, the least developed problem is that of the organization of communication between the student and the machine, i.e., a question about reception and treatment of information received by the student. The solution to this problem will require the combined efforts of teachers

psychologists, and engineers. In principle a machine can transmit a test from magnetic tape, put out a printed text with illustrations, and, finally, with the help of a sound film to imitate the work of a lecturer. Each of these means has its pros and cons. As noted above, the auditory channel of perception based on its carrying capacity is noticeably inferior to the visual channel. Furthermore, its utilization is unavoidable connected with a forced rate of supply of information. Nevertheless the supply of material from a magnetic tape possesses an unquestionable advantage – cheapness and technical simplicity. Work with a printed text permits the student to make extensive changes in the rate of processing of information depending on the complexity and novelty of the material. However, in this case there is a considerable loss of emotional information. Imitation of the work of a lecturer with the help of films eliminates this deficiency, but is connected with a forced rate of spending information and is rather expensive. The optimum solution to a problem can be obtained only by means of the combined utilization of all the stated means, moreover the quantitative proportions of this combination should be clarified experimentally and by means of a theoretical investigation.

Unconditionally in the first stages of training it is useful to utilize film equipment and tape recorders, but along with the mastering of the material all the more specific importance should be given to the supply of material in the form of printed text.

Just as complex are the problems which appear in connection with the problem of the input of the students answers into the machine. The system of selective answers, although it is simple in realization, does not make it possible to train the student in the independent formulation of an answer. The best forms of input of an answer can be such: the input of the text of an answer, including formulas and numerical results, from [illegible] with the help of a mechanical plotter. Such a form of input of information in combination with the capacity of a machine to control the correctness of the proof of theorems and conclusions, made in a

more or less free sequence (in order that logically permissible transfer would not be perceived by a machine as an error), substantially enlarges the sphere of application of teaching machines. The input of an answer by voice or in the form of text, written by hand, is technically difficult and does not have any practical advantages over the input of answers from a keyboard.

A specific place in a number of thinking machines is occupied by *trainers with programmed electronic attachments*. They produce a considerable effect when teaching the control of complex combat equipment. Such trainers not only imitate the organs of control and the dynamics of change in the situation, but also control the actions of the student, fix his errors, and give indications for their elimination.

A large number of Russian and foreign trainers are known which are used for the training of fliers, navigators, radar operators, tank drivers, etc. As a rule, trainers with programmed electronic attachments are rather complex. Thus, the trainer of the firm "Curtiss-Wright" for the training of strategic bomber crews contains more than 1200 electron tubes, up to 800 potentiometers of various types, and about 250 electric motors and servomechanisms. However, in spite of the complexity and high costs, such trainers are very effective; according to the information of the foreign press, the cost of training crews with the utilization of trainers is approximately 30% lower than normal, the crews are better prepared for actions in emergency situations, and the general time of training is sometimes shortened by 20%. The trainer "Curtiss-Wright" makes it possible to simulate a 24-hour flight in 1.5 hours. In all possibility namely trainers will be especially useful for the troops.[1]

* * *

Programmed training has attracted a large number of enthusiasts. In the forces and military training institutions in recent years

[1]It must be noted that with the correct procedure of utilization of technical means and thinking machines, the student is innoculated with the habit of constant, so to say, ordinary utilization in his work of cybernetic and electronic devices, which by itself is completely useful.

several interesting and useful teaching machines and trainers have been developed and the classes equipped with programmed training. In many cases the doubtless pedagogic success confirms the fruitfulness of the concept of this method. However, along with successes one ought to note the failures and disappointments which were experienced by some instructors and even entire pedagogic associations. Sometimes the utilization of programmed materials proved to be too complex, distracted the attention of the students from the content of the course, the knowledge of the student became formal and inflexible, a creative approach to the material was lost, the investments of pedagogic of work on each element of knowledge being reported to the student were not shortened, but, on the contrary, increased.

The reasons for these failures lie mainly in the fact that the development of the theoretical bases of programmed training - its pedagogic, psychological, technical, and economic bases - still falls behind the requirements of practice. There where experience and intuition prompted the teachers a correct solution, the effect was positive, but where these qualities were not grasped enough, pedagogic theory could not be of actual help. Therefore now the research centers, such, as the Laboratory of Programmed Education of the Institute of Psychology APN USSR, the Institute of Psychology AN UkSSR, the Laboratory of Programmed Education, MSU, and others, are engaged mainly not in the engineering of specific teaching machines or in the development of specific programmed courses, but mainly in the solution of cardinal problems.

One of such problems is the determination of the criteria of effectiveness of training. The utilization of programmed materials and of teaching machines is not an end in itself (which enthusiasts sometimes forget). These methods and means have a practical value, if they facilitate an increase in the effectiveness of education and training, they increase the productivity of pedagogic work.

At first sight the criteria of effectiveness of training are clear up to a limit: training is more effective, when it gives more

extensive and durable knowledge with shorter periods and economic investments. This means that it is necessary to attain the maximum of two first indices and to reduce to a minimum the two latter. However, practice most frequently places questions so that it is necessary to compare various indices between one another, to evaluate their interaction, and to find the equivalents of interinfluences. For example, on which economic investments is it possible to go, let us say, for the sake of increasing the durability of knowledge? Inasmuch as the indices, on which the quality of training is evaluated, do not always lend themselves to a quantitative appraisal, this problem becomes very complex. Three years ago the author of the book has occassion to become acquainted with a machine-controller which was built in one of the army units. The machine has imposing dimensions and was beautifully formed. On its development several officers and sergeants worked for a number of months. And although potentially it could increase the productivity of pedagogic work, this did not occur. The fact was that sergeants of only one unique speciality could be trained on it.

It is natural that initial investments during the introduction of a new method always exceed the average level. The machines developed during this period, as a rule, are redundantly complex. This is unavoidable. Nevertheless economic considerations when evaluating the effectiveness of training cannot be disregarded. In this sense it is hardly expedient to program a course which will be read only once. Indeed for the development of the program of a two hour exercise (without considering technical formulation) from 25 to 50 hours of the work of the most qualified and experienced instructors is expended. Therefore, before applying the method of programmed training, it is necessary to evaluate the stability of the course, how massive and systematic will be the utilization of programs and machines.

Today in the Soviet Union and abroad several tested and successful procedures exist which make it possible to quantitatively evaluate and compare various systems of training according to volume and

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Today in the Soviet Union and abroad several tested and successful procedures exist which make it possible to quantitatively evaluate and compare various systems of training according to volume and

durability of knowledge, the period of training, and its economy.[1] However, in their majority these procedures stem from the fact that the question of which specialists should be trained, the latitude of profile, the time for incorporation into the system after the completion of the training institution, and other indices which are external for the higher educational institution, are postulated simply while they themselves also must be evaluated.

The utilization of new effective methods and means in the sphere of training requires a deeply scientific approach, it does not stand for haste and subjectivism. For the successful introduction of new methods of training it is necessary to thoroughly develop the procedure for the formulation of a pedagogic experiment. The system of training in the forces and at military training institutions is a very complex dynamic system, in which a pressure on one parameter causes ten diverse, sometimes completely unexpected aftereffects. Thus, during the check of the effectiveness of programmed training it is necessary to consider such "masking" factors as the possibility of the preconceived (it is irrespective - positive or negative) relationship of the instructors and examiners to the method being checked, the temporarily increased interest of students to something new, etc. Therefore, in setting up an experiment it is necessary to investigate ahead of time the conditions of the result of the method, i.e., when one can be confident that the pedagogic success obtained is not the result of the random confluence of circumstances, but actually the natural consequence of the utilization of the new method. For example, the multiple descriptions of pedagogic experiments, constructed on a

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[1]It is possible, for example, that the quantitative value of effectiveness of training based on formula $R = \frac{1}{\eta T} \cdot \frac{n_c - n_B}{n_a - n_B}$, where n_a - the quantity of correct answers to standardized examination questions at the end of training, n_B - the quantity of correct answers to the same questions prior to training, n_c - the quantity of [illegible] in a month after examination, T - the time of preparation in training hours, η - the cost of one training hour. The total number interrogated is proposed as constant, or the absolute magnitudes are replaced by percentage relations. It is obvious this criterion possesses deficiencies which are inherent to all "compound" criteria.

comparison of 2-4 training groups, subunits, or courses, unfortunately do not possess the necessary authenticity. As a rule a result becomes significant only with the carrying out of many observations and the introduction of mathematical statistics as laws. In this case it is important not only to collect statistical material, but also to process it scientifically. The inadequate mathematical strictness of treatment is a very frequently encountered deficiency in the posing of such experiments.

The thematics of investigations and of experiments connected with programmed training is very diverse. At various scientific centers they are currently working on the clarification of a rational relationship between programmed training and independent work with scientific literature at various stages of training. They are studying the proportions of combinations of exercises on teaching machines with the usual lectures, and they are searching for paths of averting the loss of emotional information during machine training. The question of the combination of checking of knowledge with the help of machine-controllers with the live conversation of instructor and student is being studied. No less important is the trend of the investigations, the goal of which consists of determining the optimum sizes of the dose of material in a programmed course by categories of students and each type of discipline.

At the contemporary level of development of a electronic machine building the creation of teaching machines with almost any required program is possible. However, in practice they often go over the path of "accommodation" of the psychics of the student to the deficiencies of existing technical means. Therefore there is important value in investigations directed to the solution of questions of control of a machine, the limits of its adjustment, rate, loudness, contrast, and development of logical diagrams which are most effective in the given type of training institutions. Accumulated experience already allows the approach to a centralized projecting and testing of standard technical means, teaching machines, and equipment for classes of programmed training which satisfy both psychologic-pedagogic

and technical-economical requirements. As concerns the most general methodological problems which appear in connection with the rapid development and introduction of progressive methods of education, then here there is a need of further investigation of questions connected with the clarification of the nature of training as the depiction of objective reality and the process of control of the formation of the psychic features of personality of the student, with the expansion of contradictions peculiar to the training process generally, and to programmed training specifically. Here one should include the question of formation in the students of habits of flexible dialectic thought under conditions of training according to programs, an understanding of the problem of the true place of the instructor in the process of training with the utilization of machines.

Such, in our opinion, are some problems which have to be solved in connection with the wide utilization in the forces and at military training institutions of the new methods of training, on the base of the utilization of concepts, means, and methods of cybernetics.

* * *

Let us sum up briefly the consideration of the methodological questions of the utilization of cybernetics in the training of soldiers.

A cybernetic model of the process of training is a sufficiently effective means of its investigation. It makes it possible to reveal contradictions and the weak sides of the traditional methods of training, to show the paths and methods for perfecting the training process, and rather clearly formulates the criteria of effectiveness of training. It also exposes the true place of teaching machines in the training process; they do not replace the instructor, but only increase the productivity of pedagogic labor.

Programmed training is one of the [illegible] ment of the pedagogic process. It combines successfully in itself the advantages of collective and individual training, it increases the activity and independence of the students, and it trains them for intensive mental work.

The greatest effect is achieved if the application of programmed materials is combined with the use of cybernetic teaching machine-controllers, coaches, trainers, and others. The introduction of teaching machines in the training process is especially fruitful during the study of the material part of a weapon and combat equipment, in the development of skill in its operation and the elimination of malfunctions, and also the methods of its combat utilization.

The basic goal of the application of methods of programmed training and cybernetic devices is to increase the productivity of pedagogic work, the quality of training, and its economy. However, these methods have an effect only when military-pedagogic investigation determined the specific criteria of effectiveness of measures and showed the most expedient type of programs, algorithms, and teaching machines.

4. The Methodological Questions of the Application of Cybernetics in the Sphere of Control of Troops

In recent years in the armies of the major world powers great value has been attached to the perfection of systems and processes of control of the troops. The most effective means of their perfection is considered automation and the wide implementation of radio electronics. Thus according to the American press in the US Air Force in operation and in various stages of assimilation and development there are more than 30 automated systems of control. Automated systems of control of air defense have been developed in England ("Bloodhound" and "Fire Brigade"), in France ("Strida-2") and in a number of other countries. Automated systems are known for control of the ground forces, such as "FIELDATA" (USA).

Automation is the most important assignment of cybernetics in the area of control of troops. However, the application of cybernetics in this sphere is not limited to this. The application of cybernetics to the solution to assignments for the perfection of systems and processes of control of the troops is considerably wider and more

varied. It is not accidental that the specific term "military cybernetics" came on its own. It designates a rather independent military-technical science with its own very important, extensive and specific object of investigation and specific methods and means.

In the opinion of specialists of a number of countries, at present the following paths exist for the perfection of systems and processes for the control of troops:

– the special procedure for selection and preparation of commanders and staff officers;

– scientifically substantiated selection of operational-tactical information which is necessary and sufficient for the optimum control of troops;

– search for the optimum (from the point of view of maneuverability and the possibility of introduction of new means and methods of control) organization of subunits, units, major units and their staffs;

– the introduction of NOT [Scientific Organization of Labor] methods in headquarters and control points, search for the most effective methods of treatment of operational-tactical information, the investigation of the peculiarities of thought of the commander in various systems of control, and the development of optimum algorithms of thought;

– and, finally, the automation of systems and processes of control of the troops – the development of basic principles of automation, development, and introduction of electromechanical and electronic devices for the collection, transmission, processing, storage, and depiction of information, the determination of the [illegible] tions of "the distribution of duties" between people and automatic devices in each link of control of the troops and at each level of development of science and technology.

In the carrying out of all these measures an important role belongs to the means and methods of cybernetics, which together with the theory of military art, military psychology, military pedagogy, military administration, and other sciences jointly solves the problem of increasing the effectiveness of the control of troops.

One of the methods for increasing the effectiveness and reliability of control of troops is a *scientifically based procedure for the selection and preparation of personnel for carrying out the functions of commanders and staff officers.* The first and most necessary criterion for such a selection are the moral-political qualities of the candidate. In many respects it predetermines everything else, since on them depends the desire to master the program of training and to overcome the difficulties connected with personal psychological and physical peculiarities of the individual himself. However, as testified to by the data of engineering psychology, different people differ rather strongly in the type, nature, and the speed of reactions to stimuli, in the ability to execute these or other operations, in the fatiguability of attention, etc. Moreover these data depend in many respects on innate qualities changing little in the process of education, training, and conditioning. Thus psychologists arrived at the conclusion that a considerable number of aviation emergencies and catastrophes occurs only because behind the controls there turns out to be people, who based on the structure of their nervous system and psychic mentality should not be allowed to fly an aircraft.

Based on intensity and psychic load the work of commanders and staff officers under conditions of contemporary, in particular – rocket-nuclear, war will be exceptionally severe. Commanders are obliged in a limited time, moreover under conditions of increased danger, to skillfully process a large quantity of operational-tactical information and on the basis of frequently insufficiently complete data to make responsible decisions. Therefore military psychologists have validly raised the question about the need to consider, in the selection of candidates for work in particularly responsible links of

control of troops, the physiological, mental, and psychological peculiarities of people, such as emotional steadiness, psychic strength, etc.

It is obvious that the principles of selection of personnel for staffs and control points must be substantially different than for fliers or radar station operators. In all appearances, here specific value is acquired by the investigation of the behavior of candidates in probabilistic (stochastic) situations, types of subjective preferences and adjustments characteristic for a given candidate, and also his ability to solve creative assignments (for example, of the "labyrinth" type[1]). At the same time the functions of commanders and staff officers in automated systems of control of troops will in some measure resemble the function of operators who are controlling complex technical complexes. Therefore the procedure for the selection of officers for automated systems of control of troops (ASUV) should perceive many features of the procedures for the selection of fliers, operators, and mechanic-drivers.

Whatever would be concrete procedures, the fact itself of the scientifically founded selection of candidates for work in the systems of control of troops, in particular in automated, is doubtless. It is clear that other conditions being equal a system, where personnel with a higher reaction rate are working who are subjected only to such a form of fear (sthenic) at which resourcefulness and initiative rise, and trained in the rapid processing of information, will control subordinate subunits and battle complexes more effectively than a system, the personnel of which have been selected without considering such requirements. The selection of candidates is important, but only the initial stage of the enormous work on the preparation and training of personnel for control systems. Besides general military and political preparation these officers should receive special administrative training.

[1]See D. N. Uznadze. Psychological investigations. Publishing house "Nauka," 1966.

Of course military cybernetics and automation, inputting objective quantitative criteria of effectiveness of actions and placing at the disposal of the commander more than before in the amount of processed operational-tactical information, in some measure reduce the possibility of the manifestation of subjectivism. However, its other reasons, such as the lack of comprehension of relationship of objective and subjective in an armed struggle, a low theoretical-cognitive culture, the lack of comprehension of the essence of control, and, finally, disbelief in the recommendations of science, can be cured only by the good comprehensive administrative training of commanders and staff officers.

Recently specialists on the control of troops are focusing specific attention of the moral-psychological training of personnel who are working in the control system. In all probability this is a specific reaction to the fact that in preceding period the approach to control (including development of ASUV, the determination of the criteria of their effectiveness, reliability, etc.) was too "technical." In the literature they persistently emphasized role of "human links," their influence on quality, and the reliability of systems. Indeed the officers of control systems perform calculations and solve complex logical assignments not in the quiet of a study, but under conditions of armed struggle. In making a decision frequently a commander does not have exhausting information for this, however, in issuing an order he does not have the right to display his doubt to subordinates, since already this by itself can serve as the cause for failure even under favorable conditions.

The wide introduction of automation not only does not remove, as they thought some time back, the need for the development of psychological problems of control of troops, but, on the contrary, makes them still actual and adds new problems to them.

Specifically the talk is that with the advent of ASUV the nature of the battle activity of a commander and his place in the system of control were substantially modified. In the process of realization of a combat mission the commander who is working in such a system

usually is connected with his superiors and subordinates indirectly through the technical means of transmission and processing of information. Under these conditions the order of a commander is perceived by an executor in the form of an abstract information model. However, it is known that the control of battle is not only an abstract-logical, purely rational process. The danger of the battle situation and the chronic deficiency of operational-tactical information lead to the fact that control of battle requires not only semantic, but also emotional, moral-volitional pressure on subordinates, a [illegible] of their psychics. Nevertheless the possibilities of such an emotional pressure in automated systems are reduced. With the indication method of transmission or orders the personality of the commander loses for the subordinates the features of sensual specificity and, naturally, its psychological influence is diminished.

It is known that automated systems in the first place are created there where to the capabilities of man for the processing of operational-tactical information have reached the psychophysiological limit. Therefore in such systems only the necessary minimum of information is transmitted. In this case it frequently happens that for the increase in the volume of information for the officer of the higher link, on the plotting board of which the situation and the solution of the commander appear in the logical completeness necessary for work, it is necessary to reduce the quantity of information supplied to the executor (for example, to the pilot of a fighter-interceptor). An index on the screen of a search locator of a rifle sight by no means reveals the intention of a commander in its rational-logical completeness.

In the latter case a contradiction appears in the optimum conditions of transmission of the necessary semantic and emotional information. The matter is that need of emotional information sharply increases namely in the case of a shortage of logical [illegible] faith in the commander, in his intelligence, knowledge, and battle experience are especially necessary when the logic of the commander's decision is known to the end and clear to the subordinates. On the

other hand, in automated systems of control the commander himself loses a considerable part of the specific-sensual picture of battle. The enemy, the situation, and the subordinates on his plotting board look completely abstract - in the form of marks, indices, and digits. The dynamics of battle in this case is perceived as a certain play situation, and the probability of victory or defeat is evaluated as a definite quantitative measure. In a known sense the practical picture of the struggle of the will and natures of living people is overshadowed here by the picture of competition of intellect and of technology.

Contemporary automated systems have already posed the problem of specific moral-psychological and volitional training of commanders, staff officers, and engineer-operators.

The dismissal of moral-psychological factors as a value of the "second order of smallness" in the reasonings of a commander or officer working in an ASUV is now especially inadmissible, because they are entrusted with powerful contemporary weapons. The dialectics of the role of people's masses and personalities under the conditions of nuclear rocket war is such, that together with the general increase in the role of the masses in the fates of war and peace it is necessary to consider that role which can be played by a separate personality which is provided with specific authority. Under these conditions the problem of the ideological, moral-political, and volitional training of commanders is advanced to the foreground.

In completing the discussion of the problem of selection and preparation of personnel for the systems of control of troops, it must be noted that today a specific value is acquired by the *constant training of ASUV personnel,* since the combat readiness of troops now, more than it ever did before, depends on the degree of combat readiness of the systems of control: their effectiveness and reliability in combat are achieved to the greatest degree at the price of complication of the processes of preparation of technology to the utilization and increase in the periods of putting personnel into operation.

The regular carrying out of training of personnel of the control systems in peacetime is connected with great difficulties and investments, which complicates the development of battle skills. Now, according to information of the foreign press, this led to a new requirement for the ASUV apparatus: to incorporate special blocks, imitating the battle situation and allowing the conducting of systematic training and checking of the battle readiness of personnel and technology.

* * *

An important means of increasing the effectiveness of control is the ***scientifically based selection of the information which is necessary and sufficient for the optimum control of troops.***

Objectively the quantity of information necessary for optimum control is determined by the composition of troops, their armament, and the nature and intensity of military actions. Let us say that the more diversified the structure and armament of the subunit, the more information should circulate in the system of control of the unit. This objective measure of complexity of objects of control determines the optimum volume of information flows. At the same time the concrete value of optimum also depends on the subjective characteristics of personnel engaged in the control system. The value of each bit of information depends on preparedness, experience, and intuition of commanders and staff officers, on how they achieved harmony between one another in work and became accustomed to the situation. In proportion to the increase in these characteristics the flows of information are noticeably reduced.

As a rule the objective conditions of an armed struggle create a difficulty in the obtaining of the necessary (valuable) information about an enemy and even about our own troops and neighbors. This generates the natural and necessary trend of control [illegible] make up the shortage of information. However, frequently such a trend leads to an increase in the flow of information of a different quality, never able to fill the existing blank. In this case the

false belief arises that a surplus of information is nevertheless better than a shortage. Practice shows that frequently the higher headquarters inquire at the subordinates for information, which they knowingly have at their own disposal only because they are not able to find this information themselves. In this meaning the surplus of information is equivalent to its shortage.

The assignment of determination of the optimum volume of information flows, the reduction of the redundancy of information and the increase of their value is extremely complex. The matter first of all is that operational-tactical information possesses a substantial qualitative diversity, and therefore the direct utilization of recommendations of the Shannon theory is hampered here. Only by separating from the general flow the information of a given quality (or having found a means to take into account and equalize qualities) is it possible to use quantitative criteria. Moreover in this case it is necessary to consider that a redundancy of informations increases their interference rejection, which under conditions of armed struggle is of paramount value.

Specialists in the area of control of troops and the organization of the service of headquarters consider that some documents, at first sight extremely necessary and laborious, sometimes can be replaced by simple standard information. The standardization of operational-tactical documents, strictly determining their form, content, periods, means of delivery, and the selection of addresses, can noticeably reduce the flow of information and will allow the freeing of working time of the control officers for creative work.

However, the practical realization of such a standardization requires a comprehensive investigation. Specifically, it is necessary to consider the data of psychologists who are studying operational-tactical thought. They indicate that for making a decision a commander should construct in his head a mental (conceptual) model of the combat situation, using the available information parameters - the totality of information about the thinking and solution of a higher command, about the grouping of the enemy, and about his own

troops and neighbors. In this case the correctness of the concept with which a commander approaches the understanding of the situation in the first place will depend on the structure and quality of the information model. Therefore an unskillfully carried out standardization of combat documents will become the cause of a template in the making of decisions. To avoid this the development of measures for the optimization of the flows of operational-tactical information and the standardization of information is usually charged to qualified officers, without resorting to "amateurism" in this complex and delicate matter.

An important role in the perfection of the systems of control of troops is played by the *optimization of the organizational structure of subunits, units, major units, and their staffs*. It makes it possible to increase the maneuverability of troops and facilitates the introduction of new means and methods of control.

The organizational structure of forces and headquarters is determined by a whole series of factors, caused by the tactical-technological data of weapons and battle equipment which is found in the armament, by the tactics of contemporary combat, by the moral-political qualities of personnel, and also by the preparedness of officers and the level of development of means and methods for the control of troops. The complexity of the solution to the problem of increasing maneuverability lies in the fact that the structure of the forces is determined by the whole *complex* of requirements, and that is why far from always the satisfaction of only some arrangements of maneuverability will increase the total combat capabilities of the troops. Thus, the consolidation of subunits can lead to a lowering of their maneuverability, and a breaking up into smaller units – to a decrease in fire power and independence. Therefore the assignment of optimization of structure for the purpose of increasing maneuverability is solved not apart, but on the basis of *comprehensive* calculation of possible aftereffects.

Even if the problem of maneuverability is broken down, we find contradictory requirements, the simultaneous fulfillment of which

requires a reasonable compromise. Actually, in striving in any case to guarantee the utmost reticence of control, we will be forced to differentiate and reduce the flow of operational-tactical information so much that control in such a system will lose flexibility, and possibly continuity. Consequently, a system, which is better in *one* respect, will not necessarily be better *in all respects*.

For the past an approach was characteristic in which the ruling trend was to make each parameter of a system the best individually. The contemporary systematic approach to the investigation of complex structures speaks the reverse. The most probable is namely that variant of the solution to a problem, when *each* of the requirements in the system is solved not in the very best manner (for example, neither maximum reticence, nor maximum flexibility, nor maximum operative status, etc., are achieved), however, *on the whole, in a complex* this solution in the given time is the best. "Common sense," requiring the maximum of each parameter to be attained, is applicable only in the case of elementary systems. In respect to complex systems it comes forward as the antipode of science and leads to subjective appraisals.

During the investigation of organizational structure it is important to consider the level of the administrative preparation of officer personnel and the degree of development of the means of control of troops. Specifically, it is necessary to consider the effects, caused by the automation of control such, as the possibility of decreasing the number of intermediate steps, the reduction of hierarchical stairs, "rectification" of control systems, the redistribution personnel, change in the requirements for its capabilities, preparation, and qualification. One should also consider the already mentioned effect of the possible reduction of personal contact and exchange of emotional information and take appropriate measures ahead of time.

At the same time it is important to understand, that far from any organizational structure of automation of control of troops can give an effect. In certain cases an attempt to incorporate new means

and methods of control while preserving the multistage hierarchical structure can lead to disappointing results. It can even happen that, without substantially raising the operational status of control, automation will only lower the reliability of a system and increase the staffs. Conversely, with a correspondence of the organizational structure of troops and headquarters to the requirements of automation, as a rule it is possible to obtain a steady positive effect.

Let us note also that the organization of a control system, wonderfully suited to the present-day level of development of armament, tactics, and methods and means of control, tomorrow can be unsuitable in general and the search for an optimum structure will have to begin again. There are no absolute solutions which exist outside of time and are not related to a specific level of developments of military affairs.

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One additional trend in the perfection of systems for the control of troops is the *introduction of the methods of NOT in headquarters and control points, the search for the most effective methods of treatment of operational-tactical information, the investigation of the peculiarities of thought of the commander in various systems of control, and the development of the optimum algorithms of thought.* The introduction of NOT methods in work of headquarters and control points represents a rather wide circle of measures. It embraces the organization of the working place for the officer, the selection of illumination, the determination of optimum sizes and form of tables, nomograms, and ruler, and the scales of maps. This includes the working out of a rapid and calm rhythm, a business style of operation of headquarters, and coordination and mutual understanding.

Specialists have found the dependence of the productivity of mental work on the illumination of the working place, the colors and size of objects, utilized in the course of work, and in the case of the utilization of devices and automated means for depicting information — on the characteristic of their scales and screens. The eyes

are tired most strongly by a blue-violet color, and the least – by green. The greatest visual discomfort, i.e., a sense of stress and inconvenience, is caused by the presence of blinding sources in the field of vision. In this case especially strong blinding effect is possessed by yellow and red light. The large drops in brightness are inadmissible even for the signaling of emergency situations.

The contrast sensitivity of sight, its keenness, the quickness of perception and fatigability depend not only on the illumination and the colorfulness of the working place and screens, but also on the general illumination of the CP premises [command post] or operator's room. Unsuccessful illumination causes tiredness of the muscular apparatus of the eye which ensures the possibility of accommodation, change in the diameter of the pupil, and the mobility of the eye. Tiredness is developed especially rapidly if the operator has to frequently transfer view from a plotting board (a screen), located at a close distance, to a signal panel set back in the depth of the premises.[1]

Investigations showed also that the productivity of mental work substantially depends on the level of audible noises, vibrations, and the composition of the air. Thus, in the experiments conducted by the psychologist K. Ioseliani shaking with an amplitude of 0.4 mm and a frequency of about 60 periods per second in all the experimental subjects lowered the productivity of thought almost two times, moreover after the curtailment of vibration only three of the forty experimental subjects rapidly regained normal productivity. In the case of oxygen deficiency the rate of work is barely lowered, but then the number of errors increases sharply.[2]

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[1] See B. F. Lomov. Man and technology. Publishing house "Sovetskoye radio," 1966.

[2] See K. Ioseliani. The effectiveness of mental activity depending on its tempo. "Problems of psychology," 1968, No. 1.

In connection with this a series of contradictory requirements appears. On the one hand, for increasing the effectiveness of control it is necessary to strive to ensure the maximum comfort for personnel. Investigations showed that the regulation only of illumination and noise can increase the productivity of work by 25%. However, to preserve this comfort for a long time under practical battle conditions in the majority of links of control it is not possible. A sharp passage to worse conditions, as a rule, causes the additional lowering of the productivity of mental activity and strongly influence the overall psychic state of people. An opposite requirement appears: to guarantee the unpretentiousness of systems, to provide spare variants, and to constantly train personnel for work in emergency situations.

Measure for NOT in the organs of control consider also the age peculiarities of various groups of soldiers. Investigations showed the presence of a stable dependence of the rate of reactions to stimuli, sensitivity, and functional mobility of the visual and auditory apparatus, and also the ability to endure overloads, vibration, and oxygen starvation on age: in approximately 30 years all these indices begin to be lowered. Therefore the solution to the problem proposes two types of measures: on one hand, the distribution of functional duties in accordance with age-qualification peculiarities, and on the other - the adjustment of the equipment of working places and devices for depicting operational-tactical information to most probable age of the given category of soldiers. Let us say the devices for depicting at the CP of a battalion or regiment should be different than at the CP of an army; the devices and equipment should have a sufficient range of adjustment in order to take into account the individual peculiarities of each individual soldier.

An important measure in the NOT system is the development of a rapid and calm rhythm, business style of work of the organs of control, coordination, and mutual understanding. For this it is necessary to think out in detail the sequence of operations being executed by various soldiers, to establish strict time norms, and to accurately

determine the volume and content of documents being worked on by each soldier. In aviation headquarters for this goal they apply network planning specifically.[1]

At the same time the development of business style requires the calculation of personal qualities of officers, their harmony with each other, confidence, respect, and readiness to come to assistance. Frequently personal moments ("psychological incompatibility") create unnecessary stress, noticeably reducing the effectiveness of control. The data from psychology and pedagogy testify that already in the appointment of officers it is possible in some measure to take into account whether they can achieve harmony in work with the commander, the chief of staff, and the association of officers. However, even in this case it requires a great deal of work by the leaders and political workers in order to unite an association.[2]

An indispensable condition for increasing the effectiveness of control is presence in officers of a sufficient reserve of operational-tactical and also military-technical knowledge. Without them even the most abundant current information is depreciated. However, knowledge alone is little, it is still necessary to have a *high culture of thinking*. In most cases the very process of acquisition of knowledge noticeably increases the culture of thinking. Nevertheless the investigations of a number of teachers showed that for increasing the effectiveness of thinking special measures are necessary. Indeed it is not accidental that during such a vigorous development of science the productivity of mental work in the last 50 years grows approximately 10 times more slowly than the productivity of physical work.

A high culture of thinking first of all assumes a solid philosophical-methodic preparation, the knowledge of the laws of theory of

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[1]See "Aviation and cosmonautics," 1966, No. 11.

[2]See A. V. Barabanshchikov, A. D. Glotochkin, N. F. Fedenko, V. V. Shelyag. The psychology of the military collective. Voyenizdat, 1967.

knowledge and the skill to apply them in practice - to analyze contradictions, to reveal the essence of phenomena, to separate in a subjective pattern its objective base, etc. It proposes also the intimate knowledge of contemporary logic, the skill to perceptively (and then usually automatically) put into practice the knowledge of analysis and synthesis, induction and deduction, abstraction and ascent from abstract to concrete, conclusion by analogy, etc. Finally, a high culture of thinking requires the knowledge of the elements of the theory of a creative thought (heuristic) and the mastering of the concrete algorithms of operational-tactical thought.

The use of computers leads to the fact that an ever greater quantity of "standard" information, which does not require creative comprehension, is processed automatically. In the most perfected systems already a redistribution is noted in the specific value a formal-logical and creative dialectical thinking of officer-leaders. In time apparently this tendency will touch a wider circle of servicemen. Under these conditions doubt appears: is it worthwhile to teach people reproductive (i.e., reproducible by a standard arrangement) algorithmic thought, if in time all the formal operations will be transferred to machines? Should not one concentrate attention only on productive creative thinking, the regularities of which are almost inaccessible for reproduction in contemporary computers? For this doubt there is a reasonable bases, and the most expedient "distribution of duties" between man and machine actually consists of transferring to the machine all the formal processes which lend themselves to an algorithmic description, and to leave for man the solution of creative assignments.[1]

By itself the concept of strict regulation of cognitive activity of a commander is not new. The military specialists earlier than others understood its necessity, as a result of which the regulations and directives included clear indications about the order of understanding of combat missions, estimate of the situation, preparation

[1]See V. N. Pushkin. Heuristics - the science of creative thought. Politizdat, 1967.

and making of a decision. New in the algorithmic approach is the level of detailing of thought — its breaking up into elementary operations and of the introduction of single-valued orders about the order of their realization. Thus, for an understanding of a combat mission contemporary regulations and manuals on tactics prescribe for a commander the following: a) distinctly conceive what namely is the intention of the senior chief, b) what are the intentions of the command on the application of nuclear weapons and other means of destruction and the influence of the expected results of their application in the realization of the combat mission, c) understand that role which his subunit has to play in the achievement of the goal of the forthcoming combat actions.[1] As we see, these are sufficiently clear instructions, encompassing the basic points of the process of understanding of a combat mission. An algorithm is constructed not on its basis, but is distinguished from it by the fact that each of these points is dismembered into a whole series of more elementary operations. During the discussion of the problem of the utilization of algorithms for increasing the effectiveness of operational-tactical thought two sufficiently substantiated retorts are advanced: in the first place, the mastering of algorithms requires considerably greater work than the mastering of the situations formulated in usual manuals on tactics; in the second place, in the practice of control of troops, especially with experienced commanders, the formulation of the mission, the estimate of the situation, and the making of a decision most frequently flow not by "separations" (execute one... execute two...), but together, convolutely, when the intention appears immediately as something whole. In this case namely such a variant carries in itself the greatest change of creativity.[2]

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[1]See Tactics, page 116.

[2]Elements of "convolute" solution of an assignment the investigators observed in mathematicians, and chess players. Apparently it is one of the characteristic features of creation.

At first algorithms do not give a noticeable gain. The procedure for studying them is very complex, requires the utilization of a greater number of charts and diagrams, and it proposes the utilization of explanations which are more comprehensive than when using standard manuals. However, when the algorithm of thinking has been developed and mastered, then it proves to be considerably more laconic and pithier than the instructions of any standard manual or instructions. The structural clarity of an algorithm facilitates the exposure of the important main points of a process, the actions in which predetermine the success or failure of the solution to the entire assignment, and also helps to explain more thoroughly the operational-tactical meaning of a situation, and to justify its solution. Finally, algorithms have an irreplaceable quality to clearly achieve harmony in work under conditions of increased psychic stress, induced by the responsibility of action or by the danger of the situation.

As concerns the "mental convolution" of a solution or its "integral vision," then, as a rule it develops in a commander only after he comprehensively, part after part, thought over and solved tens and hundreds of such tactical assignments and thoroughly "suffered" over the comprehension of the given assignment. In other words algorithms by no means prevent, but on the contrary facilitate the formation of command intuition and in this sense by no means come forward in the capacity of antagonists of creativity.

Such are some of the problems appearing in the course of the introduction of NOT methods and the development of methods for the effective processing of operational-tactical information by officers operating in the systems of control of troops.

* * *

The most effective path for the perfection of systems and processes of control of troops is their *automation*, [illegible] and introduction of technical means which ensure the automation of collection, transmission, storage, processing, and depiction of operational-tactical information. Specialists consider that automation

of control of troops is the cardinal measure for increasing their effectiveness. It is recognized that with all the importance and need of the measures enumerated above they do not solve the problems which emerge completely and are the means of the extensive quantitative development of control systems on the basis of already known principles and technical means. The automation of control, on the contrary, represents an intensive qualitative jump, the transition to new principles, methods, and means. In this case automation pierces with its influence all the previously enumerated measures for the perfection of the systems of control of troops. Thus, the selection of officers for ASUV should be conducted by other criteria than for conventional systems, their training includes elements which are new in principle; the volume of operational-tactical information, necessary and sufficient for optimum control, should be determined from other calculations, it is connected with the productivity of contemporary computers; the best organizational structure is attained only by allowing for "rectification" and other effects induced by automation, and measures regarding NOT and the increase in the productivity of mental work of officers are organically merged with the assignment of optimum "distribution of duties" between man and computer.

The degree of automation of various systems of control and various links of one and the same system depends not only on the degree of need and its realization, but still also on the *capabilities* which are available to contemporary science and technology in this stage of development - on weight, overall sizes, reliability and economy of the computer, the development of the theory and practice of programming, on the degree of elaboration of the appropriate divisions of logic and psychology of mental work, and, finally, on the level of development of theory and practice.

In its assignment automation has been called on to remove and solve the maturing contradictions. However, at the same time automation in the course of its development - sometimes because of its nonuniformity, and sometimes because of the very nature of means being applied in this stage - generates new contradictions and

aggravates previously existing ones. Let us say if computers are so organically entered into systems of control of the ground forces that without them the process of control will become unthinkable, but in this case it is not possible to improve their transportability, then under specific conditions they can become a factor, limiting the mobility of the organs of control, which will be reflected on the operational status, and on the continuity of control and even on the maneuverability of troops.

On each stage of development of systems of control of troops such contradictions find a specific solution, depending on the level of development of technology of electronic machine building, general and military cybernetics, the degree of investigation of operational-tactical thought, and development of the theory of military art on the whole. The concrete level of automation of each system and every link in it depends on these factors.

The methodological problems of automation of control of troops represent the totality of a wide circle of important questions which require the special discussion of specialists — automation experts, tacticians, philosophers, and psychologists. These include questions about contradictions in the systems of control of troops which cause the need for automation, and also about the contradictions which appear in the course of automation, and about the possibilities of automation as the means of resolution of these contradictions. These include questions of the place and role of automation of control of troops during the contemporary revolution in military affairs, its conditionality by the development of armament and military art, the reverse effect of automation on the development of armament, the organizational structure of troops, and on the means and form of preparation and conduct of combat actions. This is also a question about the possibility of a logic-mathematical description and simulation of the processes of control of troops, about the peculiarities of thinking of the commander, the officer of the organ of control, and the ASUV operator, about the specific nature of their moral-psychological preparation and optimum distribution of duties between man and machine. Finally, about the tendency of changes in military professions under the influence of automation of control of troops.

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We will give some of the results of the examination of the methodological problems of the utilization of cybernetics in the control of troops.

Methods and means of technical and military cybernetics are finding wide application during the carrying out of a whole series of measures for the perfection of systems and processes of control of troops, beginning with the selection and preparation of commanders and staff officers and ending with the study of the optimum organizational structure of subunits, units, major units, and their headquarters.

The most cardinal means for the perfection of systems and processes of control is automation. Today the automation of control of troops is widely implanted in the practice of military affairs and it pierces and makes a specific print on all measures for the perfection of control of troops.

The wide application of cybernetics in the sphere of control of troops and especially the creation of automated systems require the serious, detailed development of a whole series philosophical-methodological and military-social problems, connected with the clarification of the specific nature of thinking of a commander in an ASUV, the nature of creativity and the possibilities of its simulation, the peculiarties of moral-psychological training of ASUV personnel the tendencies for change in military professions under the effect of automation, and a number of other problems.

CONCLUSIONS

In this work an attempt was undertaken from the positions of Marxist-Leninst philosophy and Soviet military science to discuss the philosophical bases of cybernetics and the methodology of its application in military affairs. The most important philosophical questions of cybernetics are the clarification of its object, method, volume and content of basic concepts, future of development, and its social (including military) value. The examination of methodological problems of the application of cybernetics in the military affairs proposes the discussion of questions of the specific nature of the sphere of control of a weapon and troops, of the paths for the perfection of systems and processes of control, of contradictions in this area, of automation as means of resolution of these contradictions, of the relationship of man and technology in the automated systems of control of troops, etc.

Although the majority of these questions in one way or another were examined in the book, it in general cannot be considered exhaustive, and the solutions proposed in it - final. The matter is that besides those shown above there is a large quantity of other philosophical-methodological problems which are important for cybernetics and military affairs, which for some reason were not brought up in this work. Moreover not all the problems touched upon here have been discussed in sufficient detail and comprehensively. Finally, this is how the question stands, because the rapid development of military affairs, cybernetics, and philosophy rejects the possibility of the

advancement of any final indisputable truths, suitable for all times. In a number of cases in the work only hypotheses, more or less suitable for further discussion have been expressed.

However, a number of conclusions are completely indisputable. This is mainly the conclusion that in proportion to the further development of military affairs the role and value of concepts, methods, and means of cybernetics in this area will constantly and steadily increase. In this case we have in mind not only military-technical, but also the sphere of scientific leading of troops, control of them in combat, the organization of training, planning, providing, shipments, etc. Therefore, the thorough development of the methodology of the utilization of cybernetics in military theory and practice is necessary, and an investigation of what will arise in the nearest and more distant future in connection with this.

The second important conclusion is that, in solving the problem of introduction of electronics and automation into the sphere of control of weapons and troops, one cannot nihilistically deny the role of technology or the role of man. They constitute an indissoluble unity. In this case the leading role always remains for man. "Our Party," said the Secretary General of CC CPSU L. I. Brezhnev in a speech at a reception in honor of graduates of military academies, "originates from the Leninist studies that no matter how high the technical preparedness of an army, man, mastering technology to perfection, remains the main, decisive force in war. This is especially important now, in the century of rocket and nuclear weapons, when the fate of war will be decided by the people who master the weapons and combat technology, who are tempered morally and physically and infinitely devoted to their native land, the Party and the people."[1]

Hence the need appears for comprehensive utilization by military personnel of scientific achievements in military construction, ensuring the intimate interdependence of science with practice, the development and utilization of genuine scientific methods for supervising

[1]"Pravda," 6 July 1967.

troops both in their training for contemporary war, and for combat actions, if they are forced on us by the imperialist aggressors.

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